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JOURNAL

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AMERICAN WELDING SOCIETY
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Eighth Fall Meeting of the American Welding Society

Those members who were fortunate enough to attend the Fall Meeting of the American Welding Society recently held in Philadelphia during the week of Oct. 8 in conjunction with the National Metal Exposition and meetings of several other societies, were very much impressed with the remarkable progress being made by our Society and by the welding industry.

The Fall Meeting was formally launched with a luncheon extended by the Philadelphia Chamber of Commerce in honor of the officers, past and present, of the societies meeting in Philadelphia. The speakers at this luncheon included Mayor Mackey and Past Mayor Kendricks, as well as the presidents of the societies concerned. The Mayor was also present at the first technical session of the Society.

There were a number of visitors from other countries, including Great Britain, Australia and Canada. These visitors were particularly impressed with the organized action of members of the welding fraternity in the United States, both in discussing their technical problems and in organizing for the solution of problems through research, exchange of experience and for the extension of welding in general. They remarked also as to the apparent lack of jealousies or differences on the part of advocates of the various processes of welding.

One of the outstanding developments in the welding field, during the past year or two, as indicated by the technical papers and discussion, was the emphasis that is being placed on procedure specifications in welding in the United States. By procedure specifications is meant a detailed analysis and control of all the items that enter into the success of good welding, including selection of materials, apparatus, design for welding, supervision, testing of the finished product and the use of qualified welders. It is becoming more and more recognized that welders should possess necessary experience and qualifications to do the particular work to which they are assigned and that they should be tested for these qualifications on exactly the type of work that they will be called upon to do. The program of the technical sessions was announced in the September JOURNAL and most of the papers presented were printed in that issue. The remaining papers, together with the discussion, will be printed in an early issue of the JOURNAL. Members of the Society are requested by the Meetings and Papers Committee to study the papers given in the September JOURNAL and submit written discussion of same in order that these may be included with the oral discussion.

The registered attendance was about 300, which compares very favorably with the technical sessions of even the larger societies when held out of town.

Inspection trips were provided to the Naval Aircraft Plant and the new welded building of the General Electric Company at West Philadelphia. A considerable number of members and guests took advantage of the opportunity to go on these trips.

A carefully planned program of entertainment was provided for the ladies attending the convention, including a luncheon and sightseeing trip around the city, and an automobile tour to Valley Forge, a bridge party, a shopping tour, a grand ball and the annual dinner dance of the Society.

Probably one of the greatest steps taken by the Society to insure the future growth and welfare of the welding industry was the inauguration of a fundamental research campaign by the American Bureau of Welding. This movement has the active support and sympathy of Na-

EIGHTH FALL DINNER, AMERICAN WELDING SOCIETY

tional Research Council. A committee has been organized on this subject under the chairmanship of Henry M. Hobart. Nearly ten universities are already launched on fundamental research in various fields of welding; others are busy formulating the problems that they will select for study. These universities include Catholic University, Carnegie Institute of Technology, Cornell University, Lehigh University, Leland Stanford University, Massachusetts Institute of Technology, Ohio State University, Rensselaer Polytechnic Institute, State College of Washington, University of Toronto, Washington University (St. Louis).

A more detailed statement of the work undertaken by this committee will be announced in a later issue of the JOURNAL, as will also accounts of progress made by the several large research committees of the Bureau.

The annual dinner dance continues to be the outstanding social event of the American Welding Society. This year the Society was particularly fortunate to secure a few speakers of international reputation, who spoke briefly and to the point.

The National Metal Exposition, and particularly the welding section thereof, was a credit to the organizations that sponsored them and to the individuals in charge and the exhibitors who helped make it a success. In this connection, the work by the chairman of the Exposition Committee, Charles A. McCune, deserves particular mention, as do also the efforts of the Philadelphia members of this committee and officers of the section, including Messrs. W. W. Barnes, C. W. Bates, J. J. Dunne, J. W. Meadowcroft, T. Millard, J. G. Norton, C. M. Rusk and R. D. Thomas.

Increased Recognition

(Reprinted from Oct. 18, 1928, Issue of *Engineering News-Record.*)

Structural welding was well within the vanguard of subjects considered at the Fall Meeting of the American Welding Society at Philadelphia last week. A third of the papers centered on structural matters, and discussion was animated and well maintained. Even in some of the sessions devoted to other welding fields—for instance, aircraft joints and machinery fabrication—structural welding discussion cropped out. This is a good sign. Since its foundation the American Welding Society in its predominant collective thinking has been concerned with such subjects as shipbuilding, pipe line construction and plate-work manufacturing. Until quite recently this collective thought has catalogued structural welding as only another interesting application of the welding art. That it had economic possibilities equal to or greater than the welding of ship hulls and pressure containers would hardly be admitted. Now a change has occurred. Although the American Welding Society as an entity has not been structural-welding conscious, it has had within it a small group of members active as the structural welding committee. This group has drawn a large following from those members of the Society not directly concerned with structural matters but anxious to support anything that is safe for welding advancement. The able leadership in and of this committee accounts largely for the present emergence of structural welding into the front rank of Society activities.

Much credit for this increased recognition of structural welding should also be given the manufacturers of welding equipment. By taking the initiative in welded building and bridge construction, by well-considered publicity campaigns and by efforts to have welding recognized in building codes they have done much to put structural welding upon a practical basis.

Fortunately structural welding is developing sanely. For this reason if for no other it is certain to find its proper place. The new attitude of the American Welding Society disclosed at Philadelphia will have an important bearing on the destiny of structural welding. And with this Society recognizing that building codes are as important as boiler codes, the civil engineering profession is assured of another virile influence in one of its important modern fields of activity. It is certain that the next year will see great strides in the welding of engineering structures.

Welded Rail Joint Activities

The major portion of this JOURNAL is given over to the Sixth Progress Report of the Welded Rail Joint Com-

mittee. Members of the Society who study this report will find many things of great interest which are also applicable to other fields.

As examples, there are cited the report by Professor Crook on "Stress Measurements in a Flat Plate" and the experiments of the Union Carbide and Carbon Research Laboratories to determine the proper temperature for preheating high carbon steel, such as used in rail which is about 0.75 carbon. The majority of these reports are practically complete in detail so that they may be studied separately and valuable conclusions drawn therefrom.

Purdue Welding Conference

Purdue University will hold a conference on welding on Wednesday, Thursday and Friday, Dec. 12, 13 and 14.

Efforts of Society Appreciated

105 Parkside Drive,
Berkeley, Cal.,
Oct. 17, 1928.

DEAR MR. SPRARAGEN:

The current issue of the Journal surely has some fine photographic reproductions in those last two papers —they look splendid and I hope will do some good in the field at large.

Professor Moser has expressed himself as very much gratified over his visit to the convention and the reception which he and the paper received.

Hoping that the good work will continue under enhanced circumstances and in the hands of those who can do the subject more complete justice.

With kindest regards.

Yours truly,
(Signed) KENNETH V. LAIRD.

Annual Meeting, International Acetylene Association

Members of the Society are cordially invited to attend the coming annual meeting of the Association to be held at the Congress Hotel, Chicago, Nov. 14, 15 and 16. Among the speakers will be Prof. C. F. Keel of Basle Switzerland, who will present some very interesting facts in regard to the European practices. The keynote address, on the first day, will be made by Professor Hoffman of Purdue University. An address of welcome will be made by Mr. W. R. Dawes, president of the Chicago Association of Commerce and vice-president of the Central Trust Company of Illinois.

A joint meeting of the International Acetylene Association and Gas Products Association will be held on Nov. 15.

Hotel reservations may be made by writing to Mr. William C. Harrison, Peoples Gas Building, Chicago.

A Correction

In the translation of Professor Dustin's study on "Metal Arc Welding," printed in our September, 1928, issue of the JOURNAL, a printer's error should be corrected, and an explanation made. The third paragraph on page 61 should have been inserted after Table B on page 60. Explanation should have been made that the modulus of elasticity under shear, referred to by Professor Dustin on page 65 as E2, is evidently just double the corresponding value that we are accustomed to designate by the symbol G.

SECTION ACTIVITIES

Chicago

The Chicago Section held its October meeting on the 5th. Moving pictures were shown entitled "A Day With the Tractor Builders." These were loaned by the International Harvester Company. Mr. F. J. Maeurer, of the Air Reduction Sales Company, spoke on "Controlling Quality in Pipe Line Welding." The paper and moving picture were extremely interesting and the meeting was a success.

Boston

The Boston Section will have an Autumn Engineering Tour on Oct. 19

to South Portland, State of Maine, for members and friends of the Affiliated Technical Societies of Boston.

There will be an inspection trip, illustrated talks, outing and Pine Point clambake. A delightful day of pleasant surprises.

Boston Engineers and friends are invited to South Portland on Oct. 19 to inspect the new plant of the Maine Steel Products Company.

The inspection includes a new building fabricated entirely by the electric arc-welding process—one of the first buildings to be so erected—and the interesting welding of large Sargent snowplows carried on within it.

The program schedule for this day is: 9:15 A. M., assemble at Everett; 9:30 A. M., auto caravan and police escort leave Everett; 12:00 noon, lunch at Portsmouth if desired; 2:45 P. M., assemble cars on entering South Portland; 3:00, inspection Maine Steel Products Company. Symposium on "Buildings and Bridges of the Future, and the Use of Electric Welding." Speakers: Prof. F. P. McKibben, electric welding consultant, Black Gap, Pa.; Mr. Paul Covey, welding engineer; Dr. A. Krebs, general welding equipment. Mr. G. C. Soule, Maine Steel Products Co.; Mr. Thomas A. Wry, General Electric Co.; 5:00 P. M., Pine Point clambake.

Canadian

A splendid technical session of the Canadian Section, American Welding Society, was held during the recent Steel and Power Show in the University of Toronto Arena. Joseph Cave, welding supervisor, Canadian General Electric Co., gave an excellent talk on the needs of the industry in Canada, stressing particularly the need for competent operators, and a yard-stick of a reliable nature to determine such competency.

A great deal of work has been done by the section through the secretary, Campbell Bradshaw, publisher of *Engineering Times*, in an effort to convert the Toronto city architect to permit, as a first step, the welding of the canopies on gasoline stations. Permission to do this has now been granted, and while this of itself is relatively unimportant, it must be admitted that it is a very definite step forward in the section's program of recognition of welding.

Cleveland

The Cleveland Section will hold its first meeting Thursday, Oct. 25, at the Engineering Society's rooms, this city. Professor Harke, of the Air Reduction Sales Co., will present his film, "Oxygen, the Wonder Worker," following a Liquid Air demonstration. It has been about three years since this stunt was pulled off on a large scale in this city, and the officers of this Section feel sure that the presentation of the film and demonstration will create an air of good fellowship among members and their friends and will help draw large crowds to their future meetings.

New York

The first meeting of the New York Section of the American Welding Society for the 1928-29 season was held on Tuesday, Sept. 25. This meeting was given over to a smoker and a "get together" meeting. There were several interesting talks and moving pictures. Those who attended enjoyed the evening very much.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-79. Acetylene welder desires position. Have had eight years' experience as repair welder and cutter. Last two years have been technical school manager and instructor in welding jobs and technical advisor for safety committee. Have worked for Curtiss Aeroplane and Motor Company. Can give good references.

A-80. Acetylene and electric welder desires position. Have had twenty years' experience as welder. Last four years was foreman welder, U. S. Welding Company. Am skilled on every phase of welding and all metals.

A Method of Bend Test Used in Germany

Directions for Welding Tests

TRANSLATED BY E. HERZOG, AUG. 29, 1928

1. *Preparation of Test Pieces:*

For either gas fusion welding or electric arc welding, the sheets are cut from pieces of boiler plate quality to a size of 600 mm. by 200 mm. Tests are run preferably in two series with sheets of 12 mm. and 6 mm. thickness. The sheets are best milled to ¾ thickness at an angle of 30 deg. along one longer side, so that two of the plates will form a 60 deg. welding groove.

2. *Welding of the Test Pieces:*

(a). Gas Fusion Welding.

Tests are to be made with welds that are hammered during the welding process and welds that are not hammered.

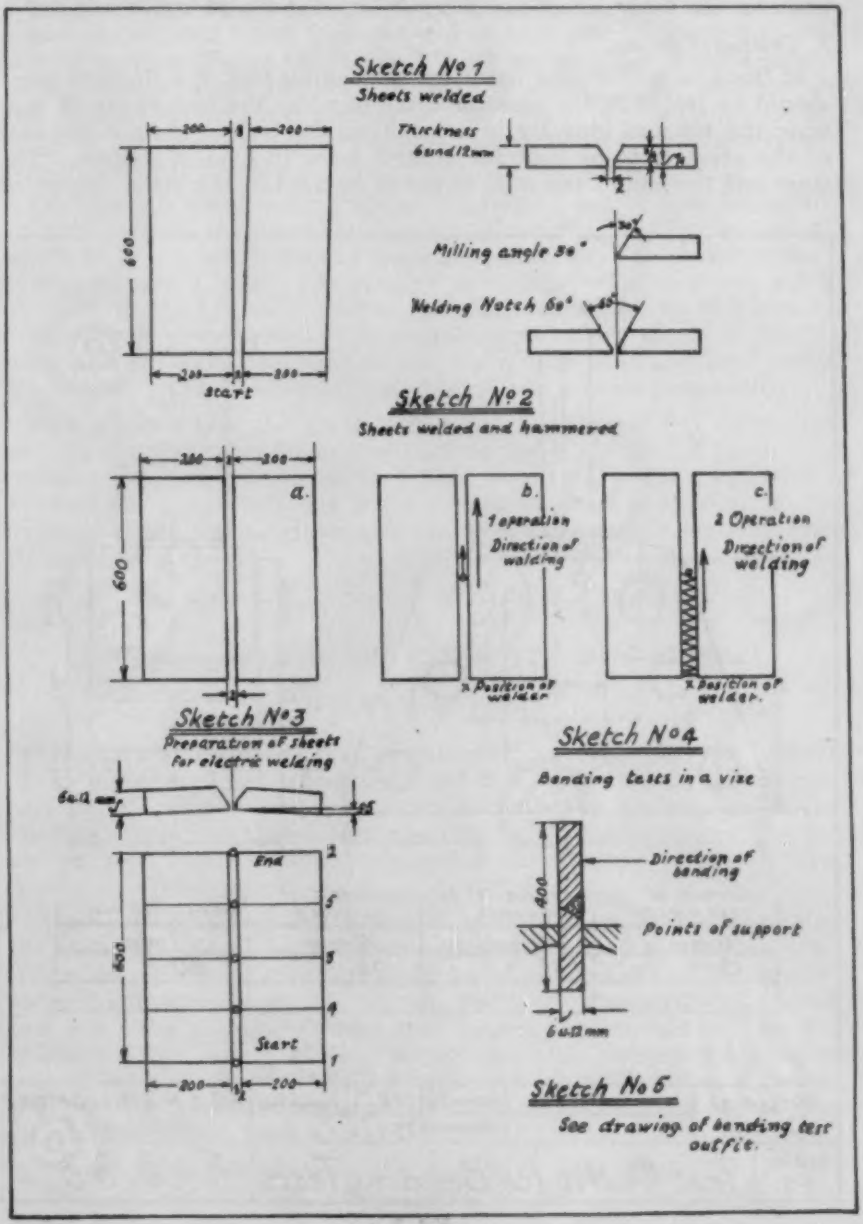
In the latter case the distance between the sheets should be 2 mm. at the beginning, and 8 mm. at the end (see Fig. 1). Welding is done in one direction continuously, and the sheets pull together automatically to the required distance. It is best to clamp the sheets at the start to avoid distortion. If the weld is hammered (which is to be done with a spherical head and a hammer of 200 g. weight) then the distance is made uniformly 2 mm. (see Fig. 2a). The welding is started in the middle, the welder working away from himself and doing first one-half of the weld (see Fig. 2b). Finishing the first half, the sheet is turned over and again working from the middle the weld is completed (see Fig. 2c).

For welding wire, one standard in this works is used, if possible a soft rolled steel wire of maximum 0.08 per cent C., 0.5 per cent Mn., traces of silicon, less than 0.04 per cent phosphorus and 0.03 per cent sulphur. Diameter to be 4 mm. on the 6 mm. sheet and 5 mm. on the 12 mm. sheet. Burner size to be chosen according to manufacturers' recommendation for each sheet thickness. Source of gas is to be so selected that the welding process will not be interrupted due to lack of acetylene.

(b.) Electric Arc Welding.

Sheets are spaced uniformly at 2 mm. for their entire length. The sheets should be raised in the middle in such manner that the edges of the weld are 5 mm. above the other edges to equalize the heat strains (see Fig. 3). Before welding the sheets should be tack welded, as shown in Fig. 3. The tack welds should be weak enough so they will completely melt down during the subsequent welding and will cause no weak spots. The welding is to be carried on in layers along the full length. Each layer is to be cleaned carefully before applying the next layer. The last layer may rise above the surface but not

more than 2 mm. on the 6 mm. sheet or 3 mm. on the 12 mm. sheet This swelling should always permit a smooth planing of the sheet without causing defective spots. A thorough weld should be made, as welding of the lower side is not permitted. The welding joint should

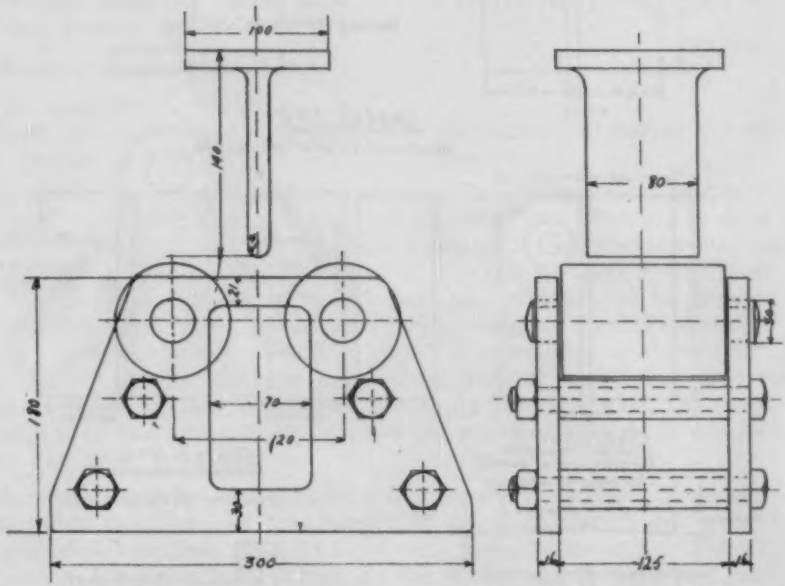


FIGS. 1 TO 4

lie diagonally to the welder. He may weld from the right or left as he is used to doing. The electrode is always negative, the sheet positive. The positive pole should always be connected to both sheets at the end of the welding seam. The welding current should be 130-135 amp. for the 6 mm. sheet and 150-160 amp. for the 12 mm. sheet.

3. *Testing Process:*

If there is no suitable outfit for a bending test, the finished piece should be tested in the vise for bending. For the test strips 30 mm. wide and 400 mm. long are to be cut from the welded sheet. The rest of the sheet is to be kept for control tests in case of failure. The start and the end of the weld is not to be used in the tests. Strips of



THICKNESS OF TEST PIECES	RADIUS "R" OF PLUNGER	THICKNESS OF PLUNGER	DIAMETER OF ROLLS
6 mm	6 mm	12 mm	90 mm
12 "	12 "	24 "	60 "

Material Steel		Drawn by	24 III 26	Wissenberg	R. A. W. Wittenberge, Abteilung T.
		Checked by	24.4.26		
Scale 1:3	Test Outfit for Bending Tests				II 2, 33

FIG. 5

10 mm. width are to be cut from the welded sheet at these points. The edges of the test strips are to be broken; the welded seam should not be removed (planed down) if less than the permissible limit.

The test strip is put into the vise, as shown in Fig. 4, so that bending occurs at the weld. The free end is then bent over by hand with the help of a piece of pipe till the first break occurs. Gas welded pieces should bend at least 120 deg., electrically welded strips at least 60 deg. without showing any cracks. As the vise only permits a bending up to 90 deg., the test piece has to be hammered or bent in a press or some fixture after that.

The test in a vise is very rough as bending cannot be done uniformly by hand. It is, therefore, preferable to use the bending test outfit shown in Fig. 5, which may be made at small cost. The outfit consists of plunger and a base. The plunger is made of axle steel and has a plate on the top to hold it straight. The radius "r" corresponds to the thickness of the sheet. The base consists of two sheets of 16 mm. thickness, two axle steel rods on the edges, four bolts and four pieces of gas pipe. The whole outfit may be set into a press very easily.

Test pieces where the breaks occur not in the weld but right next to it in the intermediate zone should be taken out of the series and replaced by two control strips. This ought to prove conclusively whether the break was due to bad material or lack of skill in the welder. If the control pieces also fail, then tests should continue with other materials.

Novel Construction Employed in Houston Airport Hangars*

THE city of Houston, Tex., prominent convention city and famous as a gulf port has recently erected three large hangars at its airport for the convenience of its flying guests. The hangars are of the all-metal type, corrugated iron sheeting being used to cover the arc welded steel super-structure, rendering the hangars absolutely fireproof.

After estimates had been received on various types of construction the Houston Airport Corporation awarded the contract for the erection of fireproof hangars of arc welded steel construction. The greater rigidity and strength of this type of construction coupled with its low cost were the deciding factors that caused the awarding of such a contract. The lowest bid submitted for wood constructed hangars was 25 per cent higher than the figure for arc welded steel construction and the lowest estimate based on riveted steel construction was 40 per cent higher.

Though these hangars were the first to be built employing the new method of construction, ample proof of the greater rigidity and

*A. F. Davis, Vice-President, Lincoln Electric Co., Cleveland.

strength of arc welded steel fabrication was offered the owners, in the large commercial and industrial buildings which have been erected in various parts of the country and whose steel framework has been entirely arc welded. The success of the new process in the structural field is attested by its increasingly rapid growth.

Credit should be given the C. J. Frankel Company for the unique design of the hangars as well as their rapid erection.

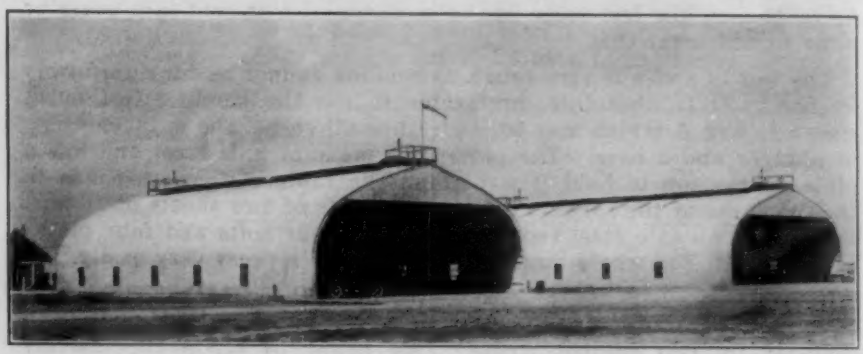


FIG. 1. GENERAL VIEW OF TWO OF THE HANGARS

FIG. 2. HANGAR IN PROCESS OF ERECTION

The three hangars, two of which are shown in Fig. 1, are typical, being 75 ft. wide, 125 ft. long and approximately 50 ft. high. The arches are made up from channel shape sections cut to form the arch when butted end to end and welded together. The entire fabrication of the arches was completed on the ground, an arch being raised into position and held in place by the welding of the channel purlins to the arches. The framework of one hangar is shown in the process of erection in Fig. 2. The columns at the closed end are also channel sections. The framework of the monitors is composed of angles and

channels. The completed arc welded steel framework of one of the hangars is shown in Fig. 3. The steel sash in the sides and end wall were arc welded in place, in fact there are no bolts or rivets in the framework of the three hangars.

All the fabricating work on the three hangars was done in the field, all connections being made by the electric arc welding process. Two portable gas engine driven arc welders were used to supply the welding current.

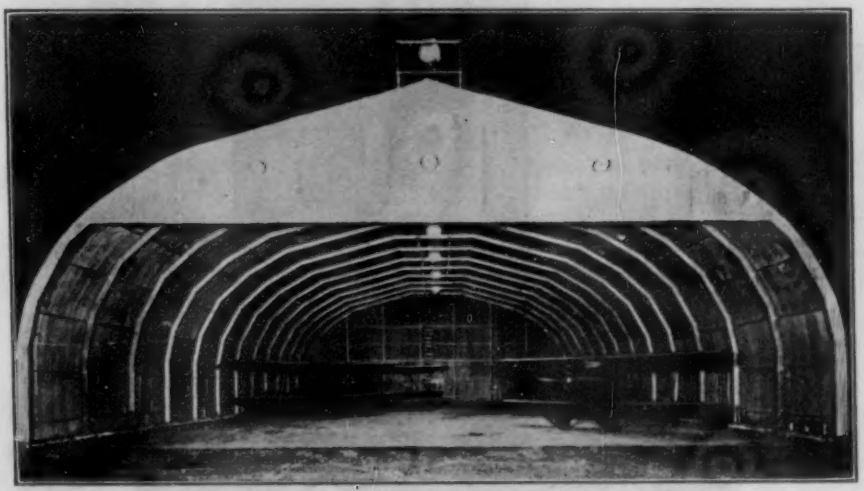


FIG. 3. COMPLETED ARC-WELDED HANGAR

The simplicity of the novel design due to the elimination of all trusses and other forms of roof bracing is an economic factor which should favor arc welded steel construction for future hangars. Another advantage of this design, due to its clear ceiling, is its practicability for hangars for blimps and similar lighter than air crafts.

Ductility Tests in Deoxidized Copper Sheet

MR. G. B. MOYNAHAN†

A LARGE firm of chemical manufacturers had been trying for some time to find a material and method of jointure which would produce a strong and leakproof container for the storage of hydrofluoric acid. It was finally decided that welding would be the best method for manufacturing tanks of this sort. It was then necessary to give careful consideration to the base metal from which the tanks were to be constructed. Deoxidized copper sheet was determined as best for this

†Linde Air Products Co.

purpose since it not only would resist the action of the chemical, but was also known to allow of high strength welds. Accordingly, the research department of this firm made some tests to determine whether the welded joint would withstand the bending or vibration to which the tanks might be subjected. It is common practice at this plant to

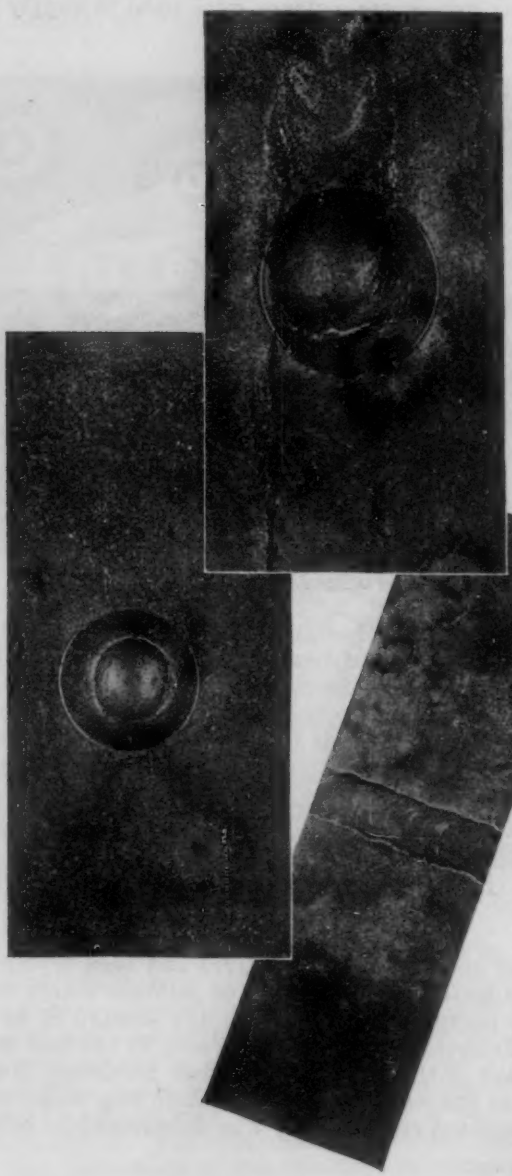


FIG. 3—TESTED TO 8,000 LB.

FIG. 1 (TOP)—TESTED PLATE OF DEOXIDIZED COPPER

FIG. 2 (ABOVE)—WELDED SEAM FOR ACID TANK

test in this manner both the welds which are made at the plant in all metals and the sheets of base metal from which their tanks are constructed.

A first test was made in a section of deoxidized copper sheet shown in Fig. 1. A hand testing machine of the ball type was used for this purpose. This machine impresses a ball into the metal and at the same time registers the force required to make the impression. Calculations are made on the depth of the depression, and these figures are used to find the relative ductility of the metal. This plate of base metal tested to 6000 lb. The second piece tested was then welded along the seam and the weld hammered to flatten it (Fig. 2). The test this time was made of the weld metal and the weld area. The second plate had 8000 lb. pressure applied to it before the slightest crack appeared. The depressed section is directly over the welded seam and is extruded fully half an inch, a thorough test of ductility.

There was no question now but that this was the most satisfactory method of joining the parts of these tanks, and accordingly production was commenced. It was found that results similar to the ones obtained could be had at any time by testing the base metal and the copper welded by competent welders.

How to Build Sheet Metal Safety Guards

A. G. WIKOFF†

WHEREVER there are exposed belts and gears, some means should be taken to prevent accidental contact with them.

Various types of guards can be easily made by welding in the shop. The accompanying sketches illustrate two types of safety guards for machinery which can be easily fabricated in the shop during the welder's spare time and as need for them may arise.

The first type of guard illustrated is for machines run from overhead shafting by means of belts. The measurements can be made according to the size of the machine. The distances from *A* to *B* should equal the distances from the floor to the center of the driveshaft of the machine. The distance from *A* to *C* should be about 5 feet in order to prevent an ordinary sized man from coming in contact with the exposed belting. From *A* to *D* should equal the size of the driven pulley plus sufficient clearance so that the guard can be easily moved away to replace a belt. The width of the guard (*D* to *E*) should be sufficient to clear the pulley.

For a gear guard of this sort, sheet steel about $\frac{1}{8}$ inch thick should be used. The larger section and the two side strips can be cut out with the oxyacetylene blowpipe according to measurements obtained. Care should be taken that the bottom lines *A* to *D* and *D* to *E* are exactly square so that the guard will stand level on the floor. One side strip is first tack-welded at *A* and then at intervals along the side. The sheets are placed as shown in the weld detail diagram (Fig. 1). This insures a

†Linde Air Products Co.

strong corner weld. If necessary the strip can be heated at *B* and bent to fit the curve. The same procedure is carried out on the opposite side. Then the two seams are welded along the entire length. Brackets or braces can be placed across the bottom of the guard as shown in the smaller diagram. Two hooks should be placed on the top and bottom of each side, as shown, or some other means taken to fasten the guard in

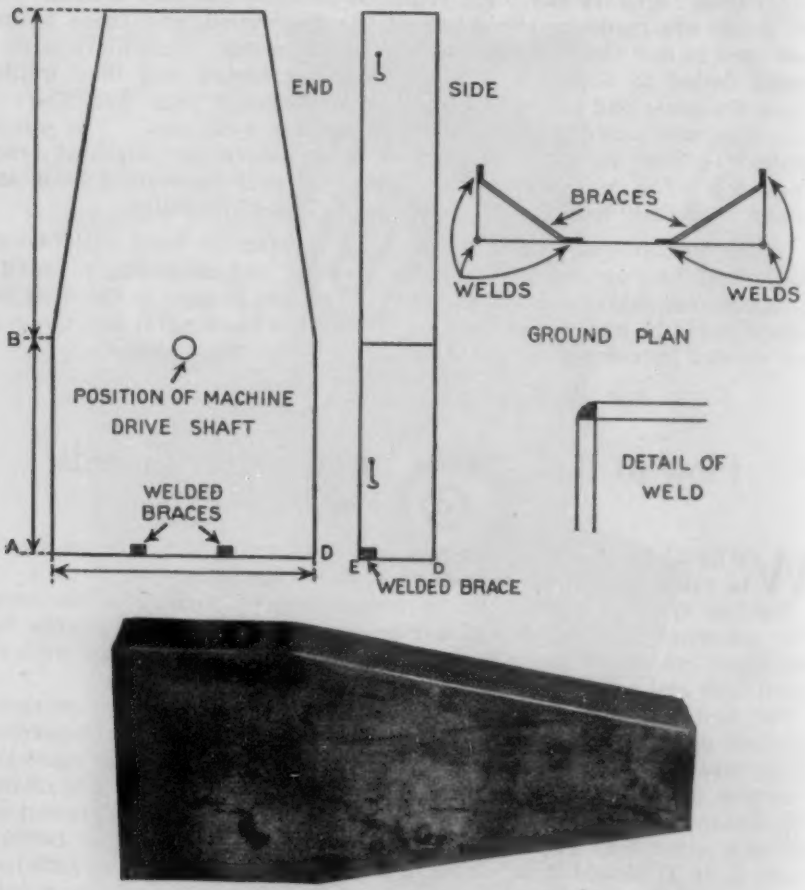


FIG. 1. MADE UP IN SPARE TIME

position against the machine. Fig. 1 shows a guard made by this procedure.

The gear guard shown in Fig. 2 is made for either chain drive or gear drive. It also is made from ⅛-in. sheet steel, and can be cut out to fit the contour of the drive mechanism. The edge of each of the sides *A* and and *B* is then measured and a side strip cut. Tack welds are made along the edge and the side piece bent to fit the curve. This type of gear guard is designed to be supported either on an angle iron framework or

bolted to the end of the machine, and is made with a hinged top.

The method of making the hinges is shown in Fig. 2. Four pieces of ¼-in. plate about 3 in. long and 1 in. wide are cut out with the cutting blow-pipe. Two of these are made with rounded ends, as shown in the diagram, and on the other two the ends are square. In the rounded ends a ¼-in. hole is cut; this is also done to one end of each of the other pieces. Fillet welds are made around the sides of the pieces, with the rounded ends, while they are in position, extending about an inch beyond the edge

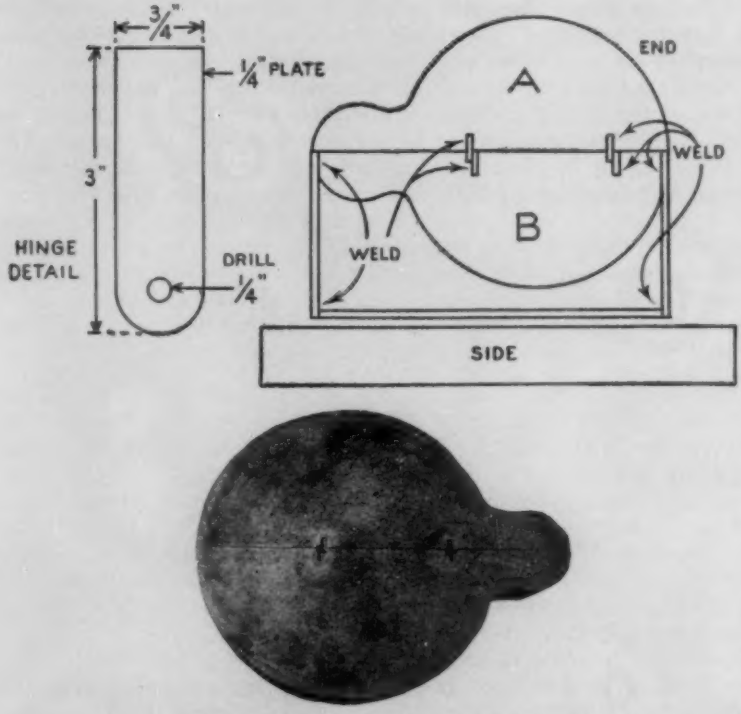


FIG. 2. FOR CHAIN DRIVEN MACHINES

of the upper half of the guard (*A*). The pierced ends of the other hinge straps are placed flush with the edge of the lower section of the gear guard (*B*) and fillet-welded to the end plate. Two ¼-in. stove bolts are placed through the two holes and tightened. They should hold the top half of the guard so firmly that it cannot be accidentally knocked out of place.

If desired, an angle iron framework can be made to hold the lower part in position. The upper section *A* can then be opened whenever it is necessary to grease or inspect the gears. The illustration shows a large gear guard that was cut and welded according to this plan.

Items like these are a great help to manufacturers in preventing accidents due to carelessness, and can often be made during the spare time of the welding operator.

A List of Welded Structures*

Prepared by
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THE following list of steel structures in which the parts are connected by welds shows that this process is no longer in the experimental stage, but is a means of fabrication so extensively used as to warrant the attention of all structural engineers and architects. Welding has also been widely adopted in joining structural shapes and plates to produce substitutes for large castings—substitutes which are stronger, more reliable, and more economical. If the accompanying list be any indication of the trend in structural engineering one must conclude that the architect and engineer in their endeavor to keep pace with the development of improvements in the building arts must at least investigate the possibility of welding as a means of fabricating certain types of steel bridges and steel buildings. In many cases it will be found that welding is better and cheaper than any other form of construction.

That responsible designers are taking this matter in hand is some assurance that its use will be directed along safe channels.

Bridges

(1). Single-track Pennsylvania R. R. Bridge over Susquehanna River at Havre de Grace (Md.), double-decked by Maryland State Roads Commission for use as a highway bridge.

(2) Single-track railroad bridge at East Pittsburgh Works of Westinghouse Co. Length of bridge, 62 ft. 4 in.

(3). Through Warren trusses with sub-divided panels for railroad bridge at Chicopee Falls (Mass.). Welded structure weighs 80 tons.

(4). Bridge connecting two buildings, General Electric Company, Schenectady, (N. Y.). Built 1921. Span 35 ft.

(5). Welded columns used in bridge for carrying coal wagons.

(6). Welding steel reënforcing rods to existing steel arch bridge over Willamette River, Oregon City (Ore.). Approximately 50,000 welds.

(7). Reënforcing Chicago Great Western R. R. Bridge over Missouri River, Leavenworth (Kan.); originally built 1893; consists of one 440-ft. drawn span and two 330-ft. fixed spans. Electric welding by American Bridge Co. involved 225,000 lb. of structural steel, 7500 lin. ft. of welding and 2000 lb. of welding steel. Reënforcing done between Feb. 28 and April 28, 1927, without interrupting trains.

(8). Princess Bridge, Melbourne (Australia); strengthened by welding.

Buildings

(9). Shop Building No. 1, West Philadelphia plant of General Electric Company. Approximately 1000 tons of beams, columns and trusses.

*Reprinted from July, 1928 Issue, *General Electric Review*. Original article also included a list of inportant tanks and test results.

Electrically welded, 1927-28. Shop 136½ ft. wide by 551 ft. long, with a wing. Trusses 58½ ft., 77 ft., and 78 ft. spans. Has bridge cranes and wall cranes.

(10). Shop building, 42 ft. long, 66 ft. wide, connecting existing Buildings 44 and 45 at Bridgeport (Conn.) plant of General Electric Company. Has four trusses of 64-ft. span supported on steel columns. Fabricated by American Bridge Co. Erected by Leak and Nelson Co., Bridgeport (Conn.). Built 1928.

(11). Shop Building No. 38 at Pittsfield (Mass.) plant of General Electric Company. Width, 60 ft. Length, 280 ft. Three stories Fabricated and erected 1928 by American Bridge Co.

(12). Five-story building at Sharon (Pa.) for Westinghouse Electric & Manufacturing Co. Built 1926 by American Bridge Co. Live load 300 lb. per sq. ft., 790 tons of steel; 70 ft. wide, 220 ft. long, 80 ft. high.

(13). Main factory building of the Lincoln Electric Co., Cleveland (Ohio). Consists of three stories and a basement, and has vertical members welded; constructed in 1916. Building is 50 ft. by 130 ft.

(14). Mill building. Roof trusses; three 19-ft. spans. Brixton, England. Area of building 20,000 sq. ft.

(15). Mill building at Tottenham, London. Built for Galvanizing Equipment Co. by Welded Construction Co. Main truss span 40 ft. with two 15-ft. side spans.

(16). Mill building. One story, built by C. B. & Q. R. R. at Eola (Ill.).

(17). Warehouse for materials of Chicago District Plant of Mississippi Valley Structural Steel Co. at Melrose Park (Ill.). Trusses, columns, and crane columns are all welded. Crane, 20-ton capacity, span 84 ft. Dimensions of building, 118 ft. by 340 ft.

(18). Material shed building. Built 1920 by Electric Welding Co. of America in Brooklyn. Roof trusses, 40 ft. span; tested by Department of Buildings, City of New York. Has traveling crane.

(19). One-story building, Derry (Pa.), built 1927 for Westinghouse Electric & Manufacturing Co. by Jones & Laughlin Steel Corp. Dimensions of building 150 ft. by 460 ft. with a wing; 336 tons of steel.

(20). Building at Youngstown (Ohio), built 1926 by Youngstown Welding Co. Dimensions 70 ft. by 220 ft.; carries traveling crane. All field erection welded; no bolts or rivets used.

(21). Building at St. Louis (Mo.) Plant of Mississippi Valley Structural Steel Company. Dimensions 30 ft. by 50 ft. All shop work welded; field work bolted.

(22). Garage building, Canton (Ohio), for Peerless Auto Sales Co. Two stories and basement. Building is 100 ft. by 150 ft.

(23). One-story garage at Dallas (Tex.), built by Dallas Power & Light Co. Two units, each 16 ft. by 140 ft.

(24). One-story building at Berkeley (Calif.). Built by Berkeley Construction Co. Dimensions, 50 ft. by 250 ft. Has two 10-ton cranes.

(25). One-story building. Built at Sharon (Pa.) for Westinghouse Electric and Manufacturing Co. in 1926. Building 40 ft. by 102 ft.; 27 tons of steel. Crane runway for one-ton crane.

(26). One-story building at East Pittsburgh Works of the Westinghouse Co. Built 1926 and 1927; 40 ft. by 100 ft.

(27). One-story garage at East Pittsburgh (Pa.) by Westinghouse Co. in 1926; 60 ft. by 90 ft.

(28). One-story steel frame building Newport News Shipbuilding and Dry Dock Co., Newport News (Va.). Building 63 ft. by 53 ft.; carries completely welded ten-ton fish belly crane.

(29). One-story building constructed in Detroit for Barnes Wire Fence Co. This structure was entirely field welded; no bolts or rivets were used.

(30). Two one-story buildings at Waukegan (Ill.). Built by General Boilers Co.; one 25 ft. by 85 ft.; the other 25 ft. by 50 ft.

(31). Steel frame of 25-story addition welded to original steel building of First National Bank Building in Detroit (Mich.), 1927.

(32). Fifteen-story steel frame addition to J. L. Hudson Co. Department Store, Detroit (Mich.); has steel frame of 12 lower stories welded to existing building of same owner.

(33). Steel frame of twelve-story addition welded to original steel building of People's Outfitting Co., Detroit (Mich.).

(34). Steel frame of four-story addition welded to original steel building of Detroit Trust Company.

(35). Welding employed in some connections for addition to Michigan Bell Telephone Building in Detroit.

(36). Addition to chemical laboratory of Westinghouse Co., at East Pittsburgh (Pa.).

(37). Two additions, each a one-story building, welded to original building of Chevrolet Motor Co., at Janesville (Wis.).

(38). Foundry building extension, 100 ft. by 54 ft. Main roof truss span, 35 ft. Built 1920 at Stoke-on-Trent, England, by Welded Construction Co. Carries traveling crane of 50-ft. span.

(39). Retort house, West Melbourne Works, Metropolitan Gas Co., Australia; 400 tons steel.

(40). Kiln and coolers at Saulte Sainte Marie Plant of Union Carbide Co. welded by Reeves Bros Co., Alliance (Ohio). Kiln, 8 ft. by 125 ft.; three coolers, 5 ft. by 55 ft.

(41). Concentration plant for Ammoniacal Liquor, Australia.

(42). Additional floor welded in between original roof and original top floor of Crowley, Miller & Co. Department Store, Detroit.

(43). Steel floor at Hershey Chocolate Co., 24 ft. by 64 ft.

(44). Roof trusses over West Yard at Decatur (Ill.). Plant of Mississippi Valley Structural Steel Co. Span 84 ft.; both shop work and field splices welded.

(45). Roof trusses over West Yard at St. Louis (Mo.). Plant of Mississippi Valley Structural Steel Co. Span 78 ft.

(46). Roof trusses, oxy-acetylene welded at Cincinnati Prest-o-Lite plant in 1926. Spans 27 to 48 ft.

(47). Roof trusses. Tested at Buffalo by Union Carbide & Carbon Co. in 1926. Span, 40 ft.

(48). Welded trusses in building for Modern Power Device Co. at Port Washington (Wis.).

(49). Roof truss. Stables at Horse Show, Olympia, England. Built 1920. Span, 14 ft.; area of building, 9,000 sq. ft.

(50). Crane runway, Coplay Cement Mfg. Co., carries crane and 10-ton bucket. Seven plate-girder spans and steel A-frames.

(51). Brackets for crane runway, General Electric Company, Schenectady (N. Y.).

Cars, etc.

(52). Locomotive tender. Built for Boston & Albany R. R. at West Springfield (Mass.).

(53). Gondola freight car. Built for C. B. & Q. R. R. by American Car & Foundry Co. in 1921. Capacity 50 tons.

(54). Annealing car, General Electric Company, Schenectady (N. Y.). Built 1921.

Cranes, etc.

(55). Large boom for derrick. Built 1922; 90 ft. long.

(56). Ten-ton fish belly crane in foundry, Newport News Shipbuilding & Dry Dock Co., Newport News (Va.). January, 1927. Span, 50 ft. 5½ in.

Frames and Towers

(57). Steel frame for large electric sign, Radio Station WGY, General Electric Company, Schenectady (N. Y.).

(58). Steel frame for boxing area lights at Philadelphia Sesquicentennial Exposition.

(59). Transmission line, tower Belgium; 72 ft. high.

(60). Transformer tower built by General Electric Company, Schenectady (N. Y.). Built 1920. Carries traveling crane. Dimensions, 40 ft. by 40 ft. by 40 ft.; 34,339 lb. of steel.

(61) Radio tower at Peking, China, 115 ft. high.

(62). Tower in Cave, California.

Ships, etc.

(63). Ship *Fullagar*. Built in 1920 by Cammel Laird & Co., at Birkenhead, England. Length, 150 ft.

(64). U. S. Coast Guard Cutter *Northland* built in 1927 at Newport News Shipbuilding and Dry Dock Co.; rudder metal arc welded, and metal arc welding used extensively on decks, bulkheads, etc.

(65). Motor boat *Sea Hornet* built in 1920 by Kyle & Purdy, City Island, New York (N. Y.). Length, 58 ft.

(66). Tugboat, built in 1920 by Electric Welding Co., Gothenburg, Sweden. Length, 52 ft., 6 in.

(67). Tugboat built 1915 by Geary Boiler Works, Ashtabula (Ohio). Length, 42 ft.

(68). 1200-ton Oil Barge *Hisco*. Built 1917 by Tank Shipbuilding Co., Newburg (N. Y.).

(69) English Channel Barge *AC-1320*. Built 1917. Length 125 ft., 9 in.

(70). Oil Barge *Independent*. Built 1924 by Saxe Providence Boiler Works, Providence (R. I.). Length, 76 ft.

(71). Steel floating caisson for dry dock. Hikoshima Drydock, Japan.

(72). Pontoon for 120-ton derrick with shell, deck, and two bulkheads welded. Built in 1925 at Norfolk Navy Yard.

(73). Pontoon for crane at Kobe, Japan; length, 65 ft.

(74). Seventeen 45-ton 172-ft. U. S. Navy battle towing targets built at Norfolk Navy Yard and Puget Sound Navy Yard between 1918 and 1927. Supersede 50-ton riveted targets previously used.

COMMITTEE ON WELDED RAIL JOINTS

Progress Report No. 6—September 1928

A Summary of Tests and Reports

Organization:

The American Electric Railway Association and the American Bureau of Welding* united in an authoritative investigation of various types of welded rail joints in commercial use through a thoroughly representative committee which was organized late in 1921. This committee has a membership of about sixty individuals, including Way Engineers of several of the larger street railway companies, representatives of manufacturers of welded joints and welding equipment, welding experts, scientists and testing experts.

Dr. G. K. Burgess, then head of the Division of Metallurgy, Bureau of Standards, and now Director of the Bureau of Standards, was elected chairman. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System, was elected vice-chairman and W. Spraragen, secretary of the Division of Engineering, N. R. C., and the American Bureau of Welding, was appointed executive secretary. Inasmuch as it was impossible to have this large committee meet more than once or twice a year, the administration of the affairs of the committee was left in the hands of a small representative Executive Committee.

Relation of American Electric Railway Engineering Association:

About $24,000 was contributed by the American Electric Railway Association, interested manufacturers, and a number of the larger street railways. The Association is acting as treasurer for the funds. Expenditures are made upon authorization of the Executive Committee and the bills are countersigned by the secretary and the vice-chairman of the committee and by a member of the Executive Committee of the American Electric Railway Engineering Association.

Objects:

The primary object of the committee is to improve each type of welded rail joint rather than to make comparative tests on the relative merits of the different types of joints.

Progress Report No. 1:

In order to compile a summary of the "present state of the art," a questionnaire was prepared on five types of welded joints in commercial use (cast, butt, bar, electric seam and thermit) and members of the committee were circularized. Answers to the questionnaire were correlated and a progress report of 73 pages printed in May, 1922. Typical problems needing further investigation were also included in the report.

*The Bureau is the welding research department of the American Welding Society and the Division of Engineering, National Research Council.

Preliminary Programs

It was agreed that the next step was to test out joints representing the "present state of the art" by testing joints of each type made by representative street railway companies and by the manufacturers. Tensile, drop, repeated impact, bend and conductivity tests were made on each type of joint. In order to distribute the work the Bureau of Standards made the conductivity, repeated impact and tensile tests and also metallurgical examinations. Purdue University made the bend and conductivity tests and the University of Illinois the drop tests.

Progress Report No. 2:

Progress Report No. 2 was published by the committee in March, 1924. It consists of seventy-two printed pages and includes information on the organization of the committee; instructions issued to railway companies for making up tests joints for the committee; methods of procedure and results in making tensile, bend, drop and conductivity tests; data furnished by the makers of these joints; photographs of specimens broken by the various tests and the discussion of the report.

Progress Report No. 3:

The Third Progress Report of the Committee on Welded Rail Joints, published April, 1925, does not include any of the results previously reported in Progress Report No. 2. It contains findings of the committee, test data and other material of interest to the committee obtained since the publication of Progress Report No. 2. Specifically it includes the remainder of results on tensile, bending and drop tests made on specimens to determine the present state of the art. The first results obtained from the repeated impact testing machine, as well as preliminary tests on the telemeter, are recorded in the report. In addition, there is also included the report of the joint examination sub-committee which carefully examined macroscopically and microscopically broken specimens; and the report of the sub-committee on Development whose function it was to draw up a program to test out the variables which affect the quality of the seam welded type of joint. The report contains 136 printed pages.

Progress Report No. 4:

The Fourth Progress Report is devoted exclusively to the test data and findings of the committee in connection with the repeated impact tests made to determine the present state of the art. This report includes a description of the method of operation of the repeated impact testing machine, charts showing location of failure, number of blows necessary to cause this failure and photographs of the broken joints. The report includes also, discussions by several individual members of the committee. It consists of 35 printed pages.

Progress Report No. 5:

The Fifth Progress Report consisting of 63 printed pages includes a series of shear test results made by the committee to develop a joint plate and method of welding, which would give a maximum area of cross sec-

tion of soundly fused weld metal in the seams. The report also includes a program of additional investigations proposed by the committee and a description of some preliminary telemeter tests made to determine stresses in rail joints under conditions simulating various degrees of poor joints and also test joints subjected to blows from the repeated impact testing machine.

Progress Report Number 6:

This present pamphlet is the Sixth Progress Report of the Committee. It does not include any of the results previously reported in Progress Reports 2 to 5 inclusive. The report includes results of repeated impact tests made on rail joints under a variety of conditions, the results of telemeter tests, and some preliminary preheating experiments. There is also included a series of strain gage measurements, the results of the tests of the "Walker" joint and some special impact tests on joints having no contact surface, as well as a second report on the shear test results. There are also given several miscellaneous reports of interest to the Committee.

Report to Executive Committee, American Electric Railway Association, August, 1927

This is a report of the progress to date of the work of the Committee on Welded Rail Joints and of its plans for the future.

History

In the Way Committee of the American Electric Railway Association the question of welded rail joints has been one for perennial discussion. In 1921 it was decided that it was desirable to organize a special committee to study this subject. Figures* show that a complete solution of the problems, if it would add five years to the average life of track, would be worth fifteen million dollars or more per year to the industry in lessened depreciation aside from decreased maintenance.

Organization

In planning for the organization of the committee it was felt that advantage should be taken of the existence of a national society devoted to the welding art, and after various conferences the Committee on Welded Rail Joints was set up as a joint committee of the American Electric Railway Association and the American Bureau of Welding, which is the Research Department of the American Welding Society and is also affiliated with the Division of Engineering of the National Research Council.

The Chairman of the Committee is Dr. George K. Burgess, who at the time of organization was head of the Division of Metallurgy of the U. S. Bureau of Standards and who is now Director of the U. S. Bureau of

*Assume 25,000 miles urban track at $60,000 per mile, including pavement. For 15 years' life, depreciation would be $100,000,000 per annum; 20 years $75,000,000; 25 years $60,000,000.

Standards; the Vice-Chairman of the Committee is Mr. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System; and the Secretary is Mr. William Spraragen, who is also Secretary of the Division of Engineering of the National Research Council.

The membership[1] of the Committee on Welded Rail Joints consists of about sixty representatives of electric railway systems, manufacturing companies interested in the electric railway industry, and representatives of universities, technical laboratories, etc. The Executive Committee of ten members includes seven street railway men.

In 1922 application was made to the American Electric Railway Association for funds[2] for the work of the Committee and an appropriation of $10,000 was made, something like $14,000 additional being raised by subscription among street railway companies and manufacturing companies interested in the electric railway industry. In addition to cash subscriptions material assistance was given the Committee in the form of materials[3] supplied without charge.

The special joints[4] to be tested by the Committee were prepared by various electric railway companies and manufacturing companies and shipped to the testing points. The testing work done for the Committee[5] has been varied and of considerable amount. Material assistance has been rendered in this work by various universities and testing laboratories, working either without charge or on a nominal basis.

Plan

The plan of precedure of the Committee has been to first determine the "state of the art" by finding out the welding methods in use by leading electric railway companies throughout the country, and then by having special test joints made up by these companies under uniform conditions, all these joints to be subjected to uniform series of tests.

This portion of the work of the Committee has been completed so that the Committee's existing reports give a complete picture of the welding art as applied to rail joints at the time the Committee undertook its study of the subject.

The type of joints investigated in the "state of the art" series were the cast iron, electric resistance (bar and butt), electric seam (carbon and metallic electrode) and thermit welded joints.

Since completing this preliminary phase, the work of the Committee has been in the development of improvements in the existing types of joints. This work has been directed to the many varieties of electric arc, seam welded, joints, as there was a very wide difference in practice among electric railway companies with this type of joint, while the other types of joints were either comparatively little used or were developed by manufacturing companies who were constantly working toward improvements in their own particular process.

[1] A list of membership is given in full in Appendix A-1.
[2] A list of contributors to the fund is given in Appendix A-2.
[3] A list of contributors of material is given in Appendix A-3.
[4] A list of contributors of test joints given in Appendix A-4.
[5] A list of cooperating laboratories is given in Appendix A-5.

Tests

The tests used by the Committee in studying these joints were the tension tests made by the U. S. Bureau of Standards, cross bending tests made by Purdue University, the drop tests made by the University of Illinois, and the repeated impact tests made by a special machine designed and constructed by the Committee and erected at the U. S. Bureau of Standards in Washington. Beside the above tests an extensive series of shear tests was carried out at Lehigh University.

Investigations

In addition to the above tests a considerable number of special investigations have been undertaken, including tests made with the otheograph, a device of the General Electric Company, and the telemeter, an electric strain gage devised by the U. S. Bureau of Standards. Beside these, quite an elaborate series of strain gage investigations is being made at Rensellaer Polytechnic Institute, Catholic University of Washington, and the U. S. Bureau of Standards. Enough has already been done along this line to show that there are heavy strains in welded joints which are set up by the welding itself. The measurement of these strains and the possibility of their elimination is a subject of study at the present time. A special pyrometer was developed by the U. S. Bureau of Standards for use in preheating and postheating tests. Metallographic investigations have also been carried out by the U. S. Bureau of Standards and the Research Department of the Union Carbide and Carbon Corporation.

Work Now Under Way

During this month (August, 1927) a series of 150 test joints are being welded at the U. S. Bureau of Standards, using the carbon arc process with a welding operator furnished by the Boston Elevated Railway Company, and the metallic arc process with a welder furnished by the General Electric Company.

These joints are being made up for the following four series of investigations:

Type of Joint—This study is undertaken to determine the best size and shape of seam in order to obtain the largest amount of weld metal of the best quality.

Heating—The effect of preheating and postheating is being studied to determine whether one or both of these heat treatments is of sufficient advantage to warrant the extra expense involved.

Base Plates—Difference in practice among railway companies in the use and non-use of base plates has caused the Committee to make an investigation to attempt to determine the amount of advantage, if any, in using base plates.

Rail Head Fit—A series of tests is being made to determine whether or not there is any advantage in having the heads of adjoining rails not only in contact but in actual compression at the time of welding.

Reports

The Committee has issued five progress reports covering the results of tests made, together with additional information and comment. The Committee has not made any formal statement of conclusions arrived at as a result of the tests so far made.

The Committee has felt that as complete information as possible should be made available promptly for the use of the industry without waiting for final conclusions. Different Way Engineers are particularly interested in particular tests and are able to draw conclusions of benefit in their own particular problems.

The carrying out of extensive research work is necessarily a slow process and it would be unwarranted to withhold all information until the Committee concludes its work. The comment already obtained on the reports shows that their interpretation is necessarily somewhat a matter of opinion and the Committee believes that by reporting full information in regard to its work, there is avoided any possible charge that valuable information is being withheld or concealed, and the great advantage is obtained that any interested person can call attention to what he believes to be a proper interpretation of the results of the tests.

Financial

Expenditure of the funds of the Committee is made only after formal appropriation by the Executive Committee, each appropriation being for a definite purpose and amount. The total amount of cash deposited with the American Electric Railway Association for the use of the Committee was $23,477. The expenditures to date have been about $15,977, leaving a balance of about $7,500. The outstanding obligations reduce this sum to about $6,000, which is the amount available for the completion of the Committee's work. The Committee will not, of course, make any appropriations in excess of the amount of funds available.

American Electric Railway Association Convention

In addition to the printed reports of the committee, meetings of the committee have generally been held in connection with the annual convention of the American Electric Railway Association, at which an opportunity for discussion and suggestion has been open to all members of the American Electric Railway Association. In several instances there have been exhibits of tested joints and the results of tests, which have brought the work vividly to the attention of those attending the convention.

Conclusion

The program of testing that the committee now has under way is given in part in the outlines in Progress Report No. 3, pages 66 and 67, and in Progress Report No. 5, pages 59 to 63. As stated above, about 150 joints are now being welded at the Bureau of Standards. It is believed that this work can be completed and the tests made with the funds at hand.

The committee is extremely fortunate in having the complete coop-

aration and support of the U. S. Bureau of Standards in carrying out these tests. A large number of technical experts from the Bureau are giving time to this work without any charge to the committee and the use of the Bureau's laboratories has also been given on a very generous scale, this committee paying only for certain supplies and apparatus that were not available and also paying in some cases for the services of the operators necessary in carrying out the tests.

Above all, the active interest of the heads of various divisions of the Bureau, who have been sitting in with the Executive Committee at their meetings, insures that the tests decided on and the methods of carrying them out are in accordance with the best technical advice available.

Appendix A-1

List of members is given on pages 38 and 39 of the Journal of the American Welding Society for August, 1927.

Appendix A-2

Companies who contributed to Welded Rail Joint Research Fund:

American Electric Railway Association.
Boston Elevated Railway Co.
Chicago Surface Lines.
Cleveland Railway Company.
Community Traction Company.
Connecticut Company.
General Electric Co.
Illinois Traction System.
Indianapolis Street Railway.
Louisville Railway Company.
Metal & Thermit Company.
Metropolitan West Side Elev. Ry. Co.
Milwaukee Electric Ry. & Light Co.
Pennsylvania-Ohio Electric Co.
Philadelphia Rapid Transit Co.
Public Service Railway Company.
Rail Welding & Bonding Company.
Terre Haute, Indianapolis & Eastern Traction Company.
Third Avenue Railway (Dry Dock, East Broadway & Battery R. R. Co.)
Union Traction Company.
United Railways of Baltimore.
United Railways of St. Louis.
Westinghouse Electric & Mfg. Co.
East St. Louis Railway Company.

Appendix A-3

Companies Furnishing Material, Equipment and Welding Apparatus other than required in making their own specimens:

Equipment

Capital Traction Company.
General Electric Company.

Hauck Manufacturing Co.
Metal & Thermit Corporation.

Welding Apparatus

Boston Elevated Railway Co.
Capital Traction Company.
General Electric Company.
Third Avenue Railway Co.

Rail

Bethlehem Steel Company.
Capital Traction Company.
Lorain Steel Company.
United Railways Co. of Baltimore.

Welding Wire

Chester Gailor.
General Electric Company.
Page Steel & Wire Company.
Rail Welding & Bonding Co.
John A. Roebling's Sons Co.

Appendix A-4

Companies Making Up Test Specimens
Boston Elevated Railway Company.
Brooklyn-Manhattan Transit Corp.
Capital Traction Company.
Cleveland Railway Company.
Detroit Street Railways.
Eastern Massachusetts Street Railway Co.
Indianapolis Switch & Frog Co.
Liteweld Company.
Lorain Steel Company.
Metal & Thermit Corporation.
Milwaukee Electric Railway & Light Co.
Montreal Tramways Company.
New Orleans Public Service, Inc.
Public Service Railway Co. of Newark.
Rail Welding & Bonding Company.
Third Avenue Railway System.
Twin City Rapid Transit Company.
United Railways & Electric Co. of Baltimore.

Appendix A-5

Cooperating Laboratories
Catholic University.
General Electric Company.
Lehigh University.
Massachusetts Institute of Technology.
Purdue University.
Rail Welding & Bonding Company.

Rensselaer Polytechnic Institute.
Union Carbide & Carbon Research Labs.
University of Illinois.
U. S. Bureau of Standards.

NOTE: *There was also attached to the original report appendices B and C. Appendix B gave a summary of the material included in each progress report. The substance of this appears in the opening portion of this progress report. Appendix C gave a summary of the expenditures to date, which was prepared as confidential information for the A. E. R. A.*

DEPARTMENT OF COMMERCE
Bureau of Standards
PROGRESS REPORT NUMBER 17
to
Members of the Executive Committee
Committee on Welded Rail Joints
on

Repeated Impact Tests of Rail Joints Having Thin Heads

In accordance with Mr. Wm. Spraragen's letter of February 17, 1927, to Professor Whittemore, rail joints 8-6 and 8-7 were prepared for the repeated impact test by planing $\frac{3}{8}$ in. from the top of the head of Joint 8-6 and $\frac{3}{4}$ in. from Joint 8-7. These joints were similar to joints which had been worn down by service. The tests were made to determine whether or not failure under repeated impact would occur in the welded seams. Seam failures are often found in welded joints in service.

These joints were selected because the failure in the three similar joints: 8-1, 8-4 and 8-5, previously tested under repeated impact had been in the plates.

As in previous repeated impact tests, the hammer weighed 400 lb. and dropped 6 in., striking the specimen at the middle of the 22-in. span. The hammer struck one of the rails 2 in. from the ends of the rails which were in contact at the joint.

The results of the tests are as follows:

Joint No.	Height Planed Off, Inches	Approximate No. of Blows per Minute	Total No. of Blows to Cause Failure
8–6	3/8	65	21,000
8–7	3/4	62	46,900

Detailed Description:

Joint No. 8-6

The plates on both sides broke at the joint. There was no failure in the welds. The first s'gns of cracks were observed after 20,000 blows, at the top and bottom of the plates at the joint.

Joint No. 8-7

The first cracks appeared, after 5300 blows, in the seams on both sides at the bottom near the joint. The crack in the bottom weld on the lip side extended from the joint for about 4 in. along the impact rail. A crack then appeared, on the lip side, in the plate and progressed upward at the joint until the plate was completely broken, after 38,800 blows. On the head side, the bottom seam was finally cracked from 4 in. from the joint on the non-impact rail, continuously to the end of the seam on the impact rail. The top seam on the head side also cracked from the end of the impact seam for about 2½ in. toward the joint. The rail head split from this point toward the lip side for 2 in. and a split in the rail head developed longitudinally along the rail about 8 in. on both sides of the joint. This longitudinal split was 2 in. from the head edge of the rail and did not occur until just before failure took place. No plate failure occurred on the head side.

It will be seen that the failure in the specimen which had been planed ⅜ in. was similar to that of the unplaned rails. In the joint which had been planed off ¾ in., the seams failed partially and one plate (lip side) broke. Since the head of this rail was so thin that it finally split, it seems impracticable to obtain seam failures by planing down the head of the rail.

A cam, which gives a 1-in. drop to the tup, has been designed and made and tests are now being carried out on rail joint 8-2 with this 1-in. drop. . . .

GEORGE K. BURGESS, *Director.*

Washington, D. C., April 4, 1927.

DEPARTMENT OF COMMERCE
Bureau of Standards
PROGRESS REPORT NUMBER 18
to
Members of the Executive Committee
Committee on Welded Rail Joints
on

Repeated Impact Test of Rail Joint with a 1-Inch Drop of 400 Lb. Tup

Seam failures are often found in welded joints in service but very few such failures have been found as the result of repeated impact tests at the Bureau of Standards. In Progress Report No. 17, the results of repeated impact tests of joints having thin heads, were given. Those failures were similar to the failures which had been found on full-head specimens and were characterized by plate failures and not by welded seam failures.

It was thought that these plate failures might have been caused by

the fact that the stresses due to the 400 lb. tup falling 6 in. were far greater than those induced by trolley car operation. From Mr. Peter's telemeter tests at Baltimore and in the repeated impact machine, it was found that a 1-in. drop produced stresses in the specimen which were about equal to those in the track due to the passage of a trolley car.

A cam giving a 1-in. drop to the tup was therefore designed and installed and rail joint 8-2 was tested to destruction with the 1-in. drop.

As in previous repeated impact tests, the hammer weighed 400 lb., and in dropping struck the specimen at the middle of the 22-in. span. The hammer struck one of the rails 2 in. from the ends of the rails which were in contact at the joint.

The results of the test are as follows:

Joint No.	Height of Hammer Drop	Approximate No. of Blows per Minute	Total No. of Blows to Cause Failure
8–2	1 inch	78	4,861,600

Detailed Description

The plates on both sides broke at the joint. Failure in the welds occurred on the head side in the rail which was struck by the tup, both top and bottom seams being cracked. This amounted to one-fourth of the length of the welds on the specimen.

This test was started on March 27 and continued with practically no interruptions until June 21, when final failure occurred. Since the failure was a plate failure, it is evident that the purpose of the test—to induce weld failure—was not attained. Plate failures, in the repeated impact machine, have predominated with the 6-in. and the 1-in. drop and on specimens with the heads planed down. It is, therefore, recommended that no further tests with a 1-in. drop be made, since the failure is the same as for the 6-in. drop and tests with the 1-in. drop are also very expensive to make.

GEORGE K. BURGESS, *Director.*

Washington, D. C., June 25, 1927.

DEPARTMENT OF COMMERCE
Bureau of Standards
Washington

PROGRESS REPORT NO. 20

To Executive Committee, Committee on Welded Rail Joints

Impact Tests on Inclined Joints

The necessary fixtures have been made and the machine was started September 15.

The joint has been set in the machine in such a manner that the outside beveled edge of the rail head is horizontal, the blow to be struck at the center of this flat.

With the joint inclined, it was found impossible to obtain a hammer drop of 6 in. However, a hammer drop of 4 in. might be easily obtained. As considerable work would be involved in changing the machine to obtain a 6 in. drop and as the work now under way is to determine whether the location of failure may be changed by changing the point of impact, we believe that the 4 in. hammer drop will serve.

Should the results of the inclined joint tests prove satisfactory and if the work is to be continued in order to compare joints tested flatwise with those tested inclined, it of course will be necessary to return to the 6 in. hammer drop.

GEORGE K. BURGESS, *Director.*

Washington, D. C., September 17, 1927.

DEPARTMENT OF COMMERCE
Bureau of Standards, Washington
PROGRESS REPORT NO. 21
to
Exec. Committee, Committee on Welded Rail Joints
on

End Pressures for Drift Tests Investigation No. 5

The following experiment was performed in an attempt to measure the compressive force tending to force the rail ends together where a drift pin is driven through the fish plate and rail web bolt holes.

A rail joint was prepared as follows: A ten-inch gage line was laid out on each fish plate, the center of the gage line being over the joint. The bolts in one half of the joint were turned tight by means of a track wrench, the other half of the joint being held by means of two bolts turned up hand tight. In the third hole a taper drift pin having an included angle of ten degrees was placed.

Initial strain gage readings were made with the drift pin loose. The drift was struck five quarter swing blows with a sledge weighing ten pounds and the gage lengths read. Gage readings were taken for each additional five blows until a total of fifteen blows had been struck.

The measurements were as follows:

No. of Blows	Fish Plate Head Side, In.	Fish Plate Lip Side, In.	Stress in Fish Plates, Lb./Sq. In.
0	0.0000	0.0000	0
5	− .0033	+ .0012	− 6300
10	− .0004	+ .0005	+ 300
15	+ .0011	− .0027	− .4800

The minus sign indicates compression.
The plus sign indicates tension.

The results obtained indicate that the method used does not give the desired information. It was observed that the drifting operation did force the ends of the rails together. However, the strain gage reading

for 5 and for 15 blows indicated a compressive stress in the fish plates which, if it had existed, would have separated the ends of the rails. Attention is directed to the fact that readings were taken on only one side of each fish plate. Any bending of the fish plate evidently would have led to an incorrect estimation of the stress. The fact that a higher stress was found for 5 than for either 10 to 15 blows also shows that this method of measuring the stress is entirely unsatisfactory and that this experiment did not give values which can be used to estimate the stress even approximately. The bending of the fish plates may have occurred because of the fact that the drift pin makes a point contact at the edge of the holes in the fish plate. This point contact may have been due to several causes: lack of parallelism of the sides of the bolt holes, or the bolt holes of the two fish plates may not have been in the line; also, as the drift is driven, the drift pin is a simple beam with a load concentrated at the center and the pin deflects. In addition, the friction of the pin would tend to cause bending of the fish plate. Strain readings were not taken directly on the rails because, due to the large cross section of the rail, it was believed that the strain gage was not sufficiently sensitive to measure the deformation.

In view of these difficulties in measuring the compressive force in a drifted joint, we feel that the loads to be applied, while the joints are welded, should be selected arbitrarily. We suggested 500 and 1000 pounds per square inch on the rail. These loads will be applied in the large Emery testing machine. As the force produced by the drift pin method would be subject to a considerable number of variations because of surface conditions, friction, etc., even though the same practice be followed throughout the investigation, there would be no assurance that comparable conditions would be produced. The two pressures are suggested for use in Investigation No. 5 because there may exist a relation between joint pressure and joint strength and if such a relation does exist, some idea of its trend may be obtained.

GEORGE K. BURGESS, *Director*,
Washington, D. C., Sept 20, 1927.

DEPARTMENT OF COMMERCE
Bureau of Standards
PROGRESS REPORT NO. 22
to
Members of the Executive Committee
Committee on Welded Rail Joints
on

Repeated Impact Tests of Rail Joints with Various Methods of Support for the Specimen

For the tests reported in this Progress Report, the rail specimen was placed so that the 400 lb. hammer struck the specimen 2 in. from the

joint. The various methods of supporting the rail are given in the following table:

Joint No.	Height of Drop, Inch	Distance Between Supports or Method of Support	Approx. No. of Blows per Minute	Total No. of Blows to Cause Failure
14–E–14	4	22-inch, specimen tipped so hammer struck near head seam	70	632,600
15–4	6	44-inch	70	58,700
14–E–13	6	18-inch	75	223,900
15–34	6	12½-inch	75	129,400
21–8	5½	Continuous support of two 2-in. wood planks	75	1,407,200

Detailed Description

14-*E*-14—The description of the manner in which this joint was tipped has been given in Progress Report No. 20, Sept. 17, 1927. Failure occurred through both plates directly under the hammer, i. e., 2 in. from the joint on the impact rail. No failure in the seams.

15-4—(44-in. span).—Both plates broke at the joint. No failure in the seams.

14-*E*-13 (18-in. span).—Both plates broke directly under the hammer. No failure in the seams.

15-34 (12-½ in. span).—The plate on the lip side broke at the joint; the plate on the head side about 2 in. from the joint, under the hammer. The lower seam on the head side of impact rail cracked from the joint for 7 in. toward the support.

21-8—Continuous support (the original base plate had been wedged off previous to the start of this test). The rail was held to the supports by clamps across the top of the specimen, spaced 20 in. apart. The non-impact rail broke 10 in. from the joint through the rail just outside the clamp. Fractures had started in the plates from the base of the rail upward to the bolt holes under the hammer after about 1,000,000 blows. No visible failure in the welded seams.

The three joints submitted by Mr. Walker are now being tested in the repeated impact machine. When those joints are finished, it is proposed to test an old joint by supporting it at one end 4 in. from the joint, i. e., 2 in. from the hammer, and at the other end as far away as possible to determine whether this method will induce failures in the welded seams.

Since no method of support has as yet been found which produces failures in the seam, it is recommended that the 24 specimens of Program 2, which are ready for the impact test, be tested on a 22-in. span and with a 6-in. hammer drop as in the Present State of the Art Series. The results will then be comparable to those from previous tests, will take relatively little time, and probably will give as good comparisons between the methods of welding and design of side plates as any of the other methods of repeated impact testing which have been tried.

An early decision on this question will enable the Bureau of Standards to continue the tests without interruption, thus obviating the necessity of training a new operator, if the tests are discontinued for a time.

GEORGE K. BURGESS, *Director.*

Washington, D. C., April 24, 1928.

DEPARTMENT OF COMMERCE
Bureau of Standards
Washington

PROGRESS REPORT NO. 24
to
Members of the Executive Committee
Committee on Welded Rail Joints
on

Tensile Tests of Rail Joints of Investigation No. 2

The rail joint specimens dealt with in this progress report are a part of Investigation No. 2, described on pages 66 and 67 of Progress Report No. 3, of the Committee on Welded Rail Joints. The details of the plates are given on the blueprints of the Bethlehem Steel Co., Steelton Plant, entitled "Committee on Welded Rail Joints, Joint Plates." Drawings No. 136448 and No. 148314, both dated 4-21-27 (Also shown in Fig. 1 of this report). The tensile tests were carried out in the large Emery testing machine. The procedure for these tests has been described on pages 4-6 of Progress Report No. 2 and on page 3 of Progress Report No. 3 of the Committee on Welded Rail Joints.

The load-elongation curves are given on the two accompanying Bureau of Standards blueprints entitled "Tensile Tests of Welded Rail Joints." The results of the tests are listed in Table 1. Those specimens which are listed as having full seams were welded during August, 1927, and those listed as having staggered seams have been welded since the Committee Meeting in Washington during February, 1928. The time and amount of welding rod used for each specimen are listed as well as the tensile strength and location of principal failure.

Table 1 shows that 11 out of the 12 joints which had full seams broke at the end of the seams through the rail. Seven of the 12 which had staggered seams broke through the rail. Staggering the seams therefore increased the proportion of specimens that did not break in the rail from one in 12 to 5 in 12. It is also notable that of the 12 joints welded by the metal arc process, all but one broke through the rail.

Some recent tests made at the Bureau of Standards appear to indicate that the shearing strength of welds depends primarily on the length of the welded seam rather than on the amount of metal deposited. With very good welding, the strengths amounted to about 13,000 lb. per linear inch. In these welded rail joints, the total length of seam on one rail end is about 48 inches (4 seams 12 inches long) and one could not expect

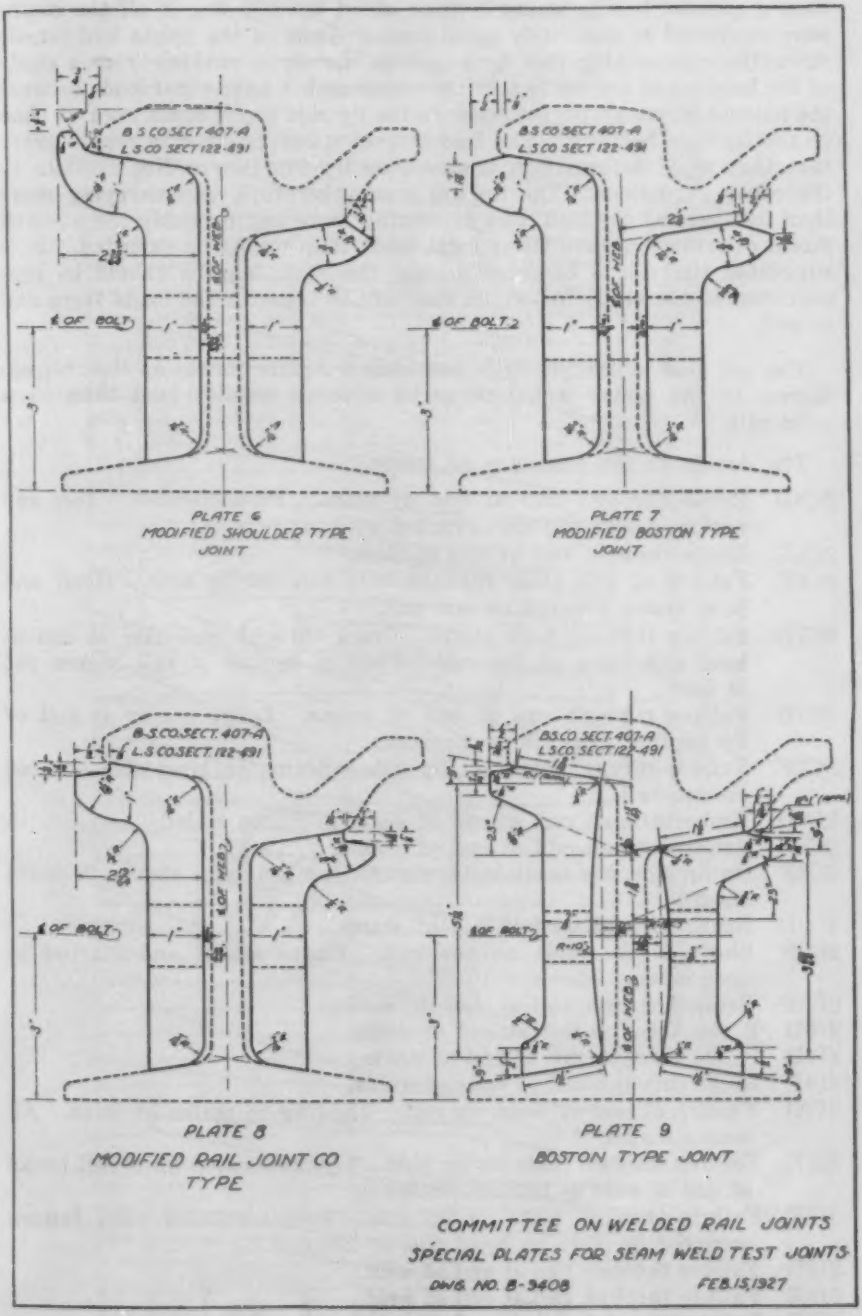


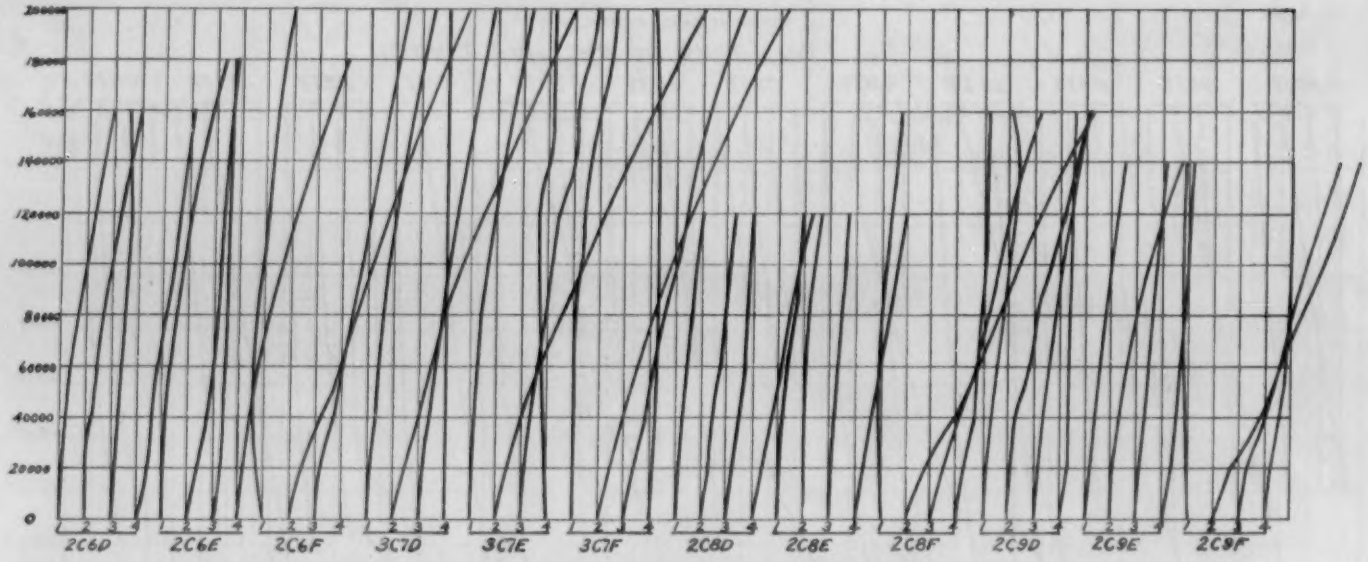
FIG. 1—SPECIAL PLATES USED BY COMMITTEE IN ITS INVESTIGATIONAL WORK

then a greater tensile strength than about 600,000 lbs. if all the seams were subjected to absolutely equal loads. Some of the joints had tensile strengths approaching this figure. It is, however, obvious from a study of the location of the welds that the seams do not have equal loads because the amount of metal, for example, on the lip side top is much greater than on the lip base below it. The load-extension curves show in nearly every case that more deformation occurred on lip top (curve No. 2) than in the other gage lines. The lip top seam, therefore, was carrying more than its share of the load, was deforming more and probably the unequal stress distribution gave lower total loads than might be expected. It is suggested that for a balanced design, the seam lengths should be proportional to the areas for which they are to transfer the loads from rail to rail.

The net area of the plates is less than 9 square inches so that tensile failure in the plates would occur at a much smaller load than in a solid rail.

The details of the tests are as follows:

2C6D Broke through rail at end of seam. Plates scaled. Top and bottom seams, lip side, cracked at joint.
2C6E Broke through rail at end of plate.
2C6F Failure of fish plate through bolt hole on lip side. Head and base seams sheared on one rail.
3C7D Failure through both plates. Crack through rail base at end of head side seam on one rail. Piece of bottom of rail broken out at joint.
3C7E Failure through rail at end of seams. Large crater at end of lip seam where failure occurred.
3C7F Failure through plate on lip side. Seams on head side sheared on one rail.
2C8D Broke through rail at end of seams. Plates scaled.
2C8E Broke through rail at end of seams.
2C8F On lip side, the north welds sheared, on head side the south welds sheared.
2C9D Broke through rail at end of seams.
2C9E Sheared the welds on one rail. Plates scaled and started to neck down.
2C9F Broke through rail at end of welds.
2I6D Broke through rail at end of welds.
2I6E Broke through rail at end of welds.
2I6F Broke through rail at ends of welds.
3I7D Failure at end of weld, in rail. Yielding in plates at joint. All seams scaled.
3I7E Failure through plate on lip side. Test continued until rail broke at end of weld at load of 268,500 lb.
3I7F Failure through plate on lip side. Test continued until failure occurred in plate on head side at 271,000 lb.
2I8D Failure through rail at end of weld.
2I8E Failure through rail at end of weld.
2I8F Failure through rail at end of weld.



SCALE OF EXTENSION IN 20": 1" HORIZONTAL = 4 DIVISIONS = .02" EXTENSION. SMALL NUMBERS 1-2-3-4 REFER TO INDIVIDUAL EXTENSOMETERS: NO. 1 ON LIP BASE, NO. 2 ON LIP TOP, NO. 3 ON HEAD TOP, NO. 4 ON HEAD BASE.

FIG. 2—TENSILE TEST RESULTS

FIG. 3—TENSILE TEST RESULTS

2I9D Failure through rail at end of weld.
2I9E Failure through rail at end of weld.
219F Failure through rail at end of weld.

TABLE 1

Results of tensile tests of rail joints of Investigation 2

Joint No.	Plate	Seams	Time, Min.	Welding Rod, Lb.	Tensile Strength, Lb.	Location of Principal Failure
Carbon arc, hand feed, two layers.						
2C6D	6	Full	105	4.02	432,000	Rail
2C6E	6	Full	81	3.64	215,000	Rail
2C6F	6	Staggered	65	2.82	471,000	Plates
3C7D	7	Staggered	70	2.79	382,000	Plates
3C7E	7	Staggered	66	2.56	220,000	Rail
3C7F	7	Staggered	95	2.81	368,000	Plates and seams
2C8D	8	Full	102	3.96	388,000	Rail
2C8E	8	Full	92	3.11	140,000	Rail
2C8F	8	Staggered	75	2.62	408,000	Seams
2C9D	9	Full	74	3.82	393,000	Rail
2C9E	9	Full	69	3.76	530,000	Seams
2C9F	9	Staggered	79	3.00	450,000	Rail
Metal arc, two layers.						
2I6D	6	Full	117	4.43	429,000	Rail
2I6E	6	Full	126	4.86	416,000	Rail
2I6F	6	Full	117	6.16	299,000	Rail
3I7D	7	Staggered	90	4.05	420,000	Rail
3I7E	7	Staggered	125	5.21	382,000	Rail
3I7F	7	Staggered	122	5.12	361,000	Plates
2I8D	8	Staggered	128	4.89	437,000	Rail
2I8E	8	Staggered	120	4.60	318,000	Rail
2I8F	8	Staggered	120	5.00	327,000	Rail
2I9D	9	Full	110	4.32	364,000	Rail
2I9E	9	Full	110	4.08	348,000	Rail
2I9F	9	Full	101	3.83	365,000	Rail

GEORGE K. BURGESS, *Director.*

Washington, D. C. May 8, 1928.

DEPARTMENT OF COMMERCE
Bureau of Standards
Washington

PROGRESS REPORT NO. 25
to
Members of the Executive Committee
Committee on Welded Rail Joints
on

Repeated Impact Tests of Rail Joints

The tests reported in this Progress Report are a continuation of those given in Progress Report No. 22. Various means have been taken to determine whether failure in the welded seams could be obtained with the repeated impact test.

Joint 7-9 was prepared for test by removing the bolts that held the plates on the rail and cutting the plates along their entire length at mid-height by an oxy-acetylene torch. The specimen was supported on a 22-in. span and struck by the 400 lb. hammer 2 in. from the joint. The height of hammer drop was 6 in.

Joint 21-4 was prepared for test by wedging off the base plate. The joint in the specimen was placed 2 in. from the hammer. One support was 6½ in. from the hammer, i. e., 8½ in. from the joint. The other support was as far from the joint as the anvil permitted. It was 24¾ in. from the joint, 26¾ from the point of hammer contact and the distance between supports was therefore 33¼ in. This method gave one support very nearly under the hammer and the other at a considerable distance from it. Height of hammer drop was 6 in.

The results of these tests are as follows:

Joint No.	Distance Between Support, In.	Approximate No. of Blows per Minute	Total No. of Blows to Cause Failure	Location of Failure
7–9	22	78	79,900	Seams
21–4	33¼ unequally divided	78	308,400	Plates

Detailed Description

7-9. Plates torch-cut along entire length.

Upper plate on head side fell off	10,200 blows
Upper plate on lip side fell off	12,900 blows
Lower plate on head side fell off	78,600 blows
Lower plate on lip side fell off	79,900 blows

21-4. One support nearly under hammer. Failure through plates near joint.

GEORGE K. BURGESS, *Director.*

Washington, D. C., May 8, 1928.

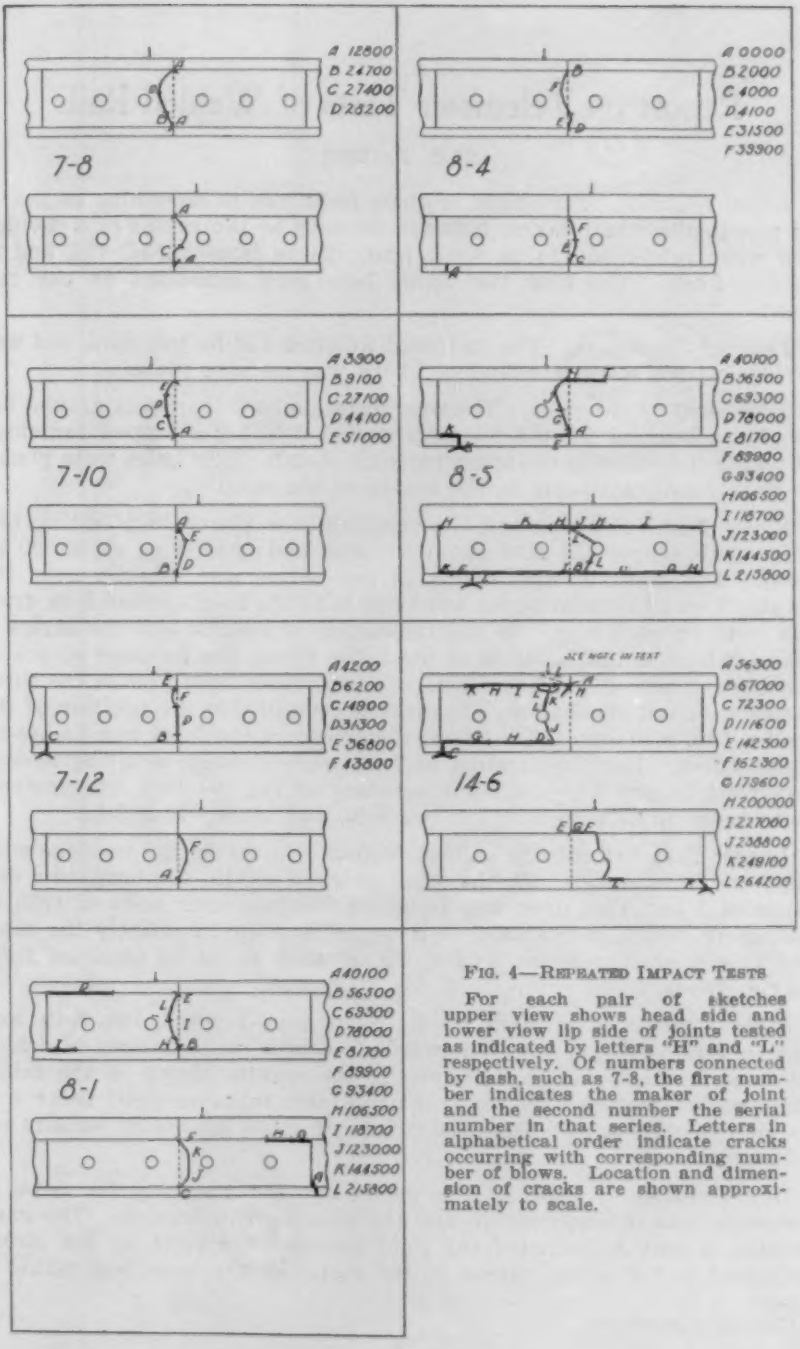


FIG. 4—REPEATED IMPACT TESTS

For each pair of sketches upper view shows head side and lower view lip side of joints tested as indicated by letters "H" and "L" respectively. Of numbers connected by dash, such as 7-8, the first number indicates the maker of joint and the second number the serial number in that series. Letters in alphabetical order indicate cracks occurring with corresponding number of blows. Location and dimension of cracks are shown approximately to scale.

Report on Telemeter Tests of Welded Rails

O. S. PETERS†

Scope of Tests. The object of these tests was to determine as nearly as practicable the relation between stresses in the seams of a welded rail when subjected (1) to static load, (2) to impact load, (3) and to service loads. The first two items have been completed on one rail joint.

Type of Specimens. The rail used weighed 122 lb. per yard and was welded with a metal electrode. There was no base plate.

Treatment of specimen. The weld metal on each seam was ground flat to give a bearing for the telemeters, and 6-40 holes tapped for studs at points indicated in the accompanying sketch. The holes were placed as nearly as practicable in the center of the seam.

Static Test. For this test the specimen was placed in a testing machine with supports 4 ft.-6 in. apart, and load applied up to 30,000 lb. total. The point of application in one series was directly over the joint. Two additional series were run with the load applied 2 in. from the joint on each side. In the tabulation of results but one series is given, which is that applied at the place where the hammer struck in the impact test. The differences in the stresses observed in the three series were not great enough to make it certain that the position of the load within a range of 4 in. about the center of the joint had an appreciable effect. Each application of load was repeated with the telemeters reset in order to check the accuracy of the results. Observations were made on 26 gage lengths, two 8-in. and twenty-four 2-in.

Impact Test. In this the rail was clamped in the impact machine with supports 22 in. apart. The hammer weighed 400 lb. and dropped a distance of 1 in. This drop was based on the telemeter tests of 1925 in Baltimore, which indicated that it would give approximately the same effect in producing stress as the impact that would be expected from service loads.

Measurements were made on fourteen gage lengths, two 8-in. and twelve 2-in. About 100 photographic records were taken, of which 49 were found usable in determining the results shown in the table. Each record was checked, and, if necessary, repeated until there was no sign of slippage of the gage points or other source of serious inaccuracy.

Interpretation of Results. The minus sign indicates that the metal of the seam was in compression and the plus sign in tension. The gage lengths A and A′ included the joint between the rails, so the stress indicated is not actual stress in the metal of the base, but rather a

†Bureau of Standards.

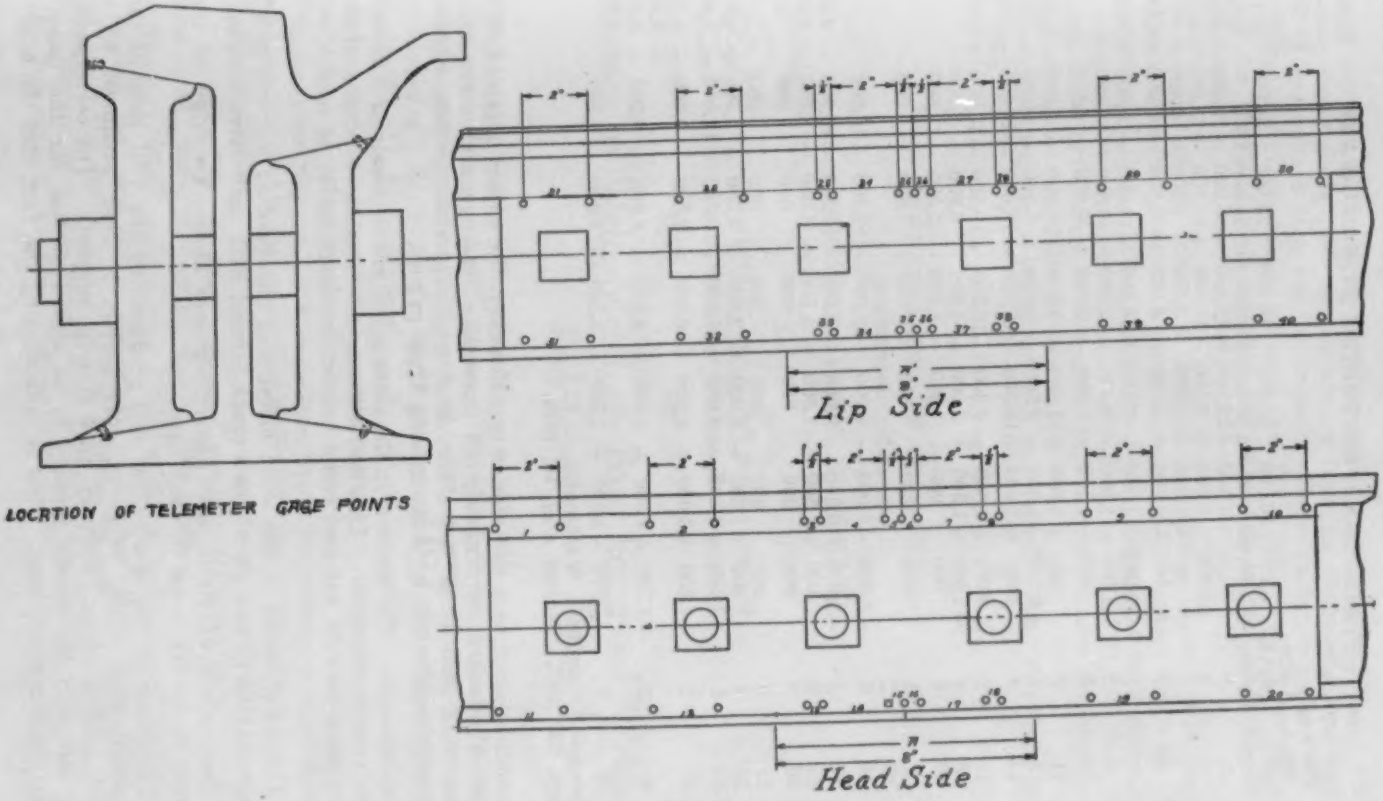


FIG. 6

Position of Gage	Gage Length, Inches	STATIC LOAD; SUPPORTS 4 FT. 6 IN. APART — Stress in Seam Metal; Pounds per Square Inch: 5,000	10,000	15,000	20,000	25,000	30,000	Impact Load 1 In. Drop Supports 22 In. Apart
A	8	+3,400	+7,500	+12,100	+15,800	+20,000	+25,600	+16,500
A′	8	+2,600	+6,000	+ 9,800	+13,500	+16,900	+21,900	+10,800
1	2	000	−1,500	− 3,000	− 3,000	− 4,500	− 8,000	
2	2	−1,500	−3,000	− 4,500	− 6,000	− 7,500	− 9,000	− 4,600
7	2	−3,000	−4,500	− 7,500	−10,500	−12,000	−15,000	− 6,200
9	2	−1,500	−1,500	− 3,000	− 3,000	− 4,500	− 6,000	
10	2	000	−1,500	− 1,500	− 3,000	− 3,000	− 4,500	
11	2	000	+1,500	+ 1,500	+ 1,500	+ 3,000	+ 3,000	
12	2	+1,500	+3,000	+ 4,500	+ 6,000	+ 7,500	+ 9,000	+ 7,100
14	2	+3,000	+7,500	+10,500	+15,000	+18,000	+21,000	+ 9,500
17	2	+3,000	+6,000	+ 9,000	+10,500	+13,500	+15,000	+11,800
19	2	+1,500	+1,500	+ 3,000	+ 4,500	+ 6,000	+ 6,000	
20	2	000	000	− 1,500	− 1,500	− 1,500	− 3,000	
21	2	000	000	000	000	000	000	
22	2	No observations						
24	2	−3,000	−6,000	− 9,000	−12,000	−13,500	−15,000	
27	2	−3,000	−6,000	− 9,000	−12,000	−13,500	−15,000	− 4,600
29	2	000	−1,500	− 1,500	− 1,500	− 3,000	− 3,000	− 4,900
30	2	000	000	000	000	000	000	
31	2	000	000	000	000	000	000	
32	2	000	+1,500	+ 3,000	+ 3,000	+ 4,500	+ 4,500	+ 4,600
34	2	+1,500	+3,000	+ 6,000	+ 7,500	+10,500	+12,000	+ 6,400
37	2	+1,500	+3,000	+ 4,500	+ 6,000	+ 7,500	+ 9,000	+ 5,700 + 6,400
39	2	+1,500	+1,500	+ 3,000	+ 4,500	+ 6,000	+ 6,000	+ 3,400 + 4,400
40	2	000	+1,500	+ 1,500	+ 3,000	+ 3,000	+ 4,500	

Bureau of Standards, Washington, D. C.
Sept. 28, 1927. Revised Aug. 14, 1928.

combination of base and side bars. However, the values obtained on A and A′ checked very closely on successive loadings and serve as a means of indicating the static load which produces seam stresses roughly equivalent to those arising from impact.

Conclusions. The stresses in the seam metal are obviously of a spotted and erratic character. This doubtless arises from the tendency of the slip between side bar and rail to shear the seam metal as load is applied.

Abnormal stress in the seam metal was observed at but one point, gage lengths 15 and 16, where a crack formed with successive loadings.

Comparison of static and impact stresses shows the sign of the stress to be the same in each case.

The stress in the base of the rail produced by the 1-in. drop of the hammer, with 22-in. supports, corresponds to that produced by a static load of about 19,000 lb. on 4 ft.-6-in. supports. The corresponding stress in the seams appears to be somewhat less for the impact than for the static load. This is indicated by the fact that the arith-

metical average of the stresses on the corresponding gage lengths for the two cases gives 7300 lb. per square inch for the static load and 6250 lb. per square inch for the impact. These values, together with the individual stress value, indicate that for a given overall stress in a rail the distribution is roughly the same for impact loads as for static loads.

As a result of the telemeter tests in Baltimore, August, 1926, and previous telemeter tests on height of drop in the impact machine, it was estimated that a 1-in. drop of the 400-lb. hammer would give approximately the stresses found in the field, or about 11,000 lb. per square inch in the base of the rail. In the present case the average stress in the base is 13,600 lb. per square inch.

Bureau of Standards, Washington, D. C., Sept. 28, 1927, Revised Aug. 14, 1928.

DEPARTMENT OF COMMERCE
Bureau of Standards

PROGRESS REPORT NUMBER 27

to

Members of the Executive Committee
Committee on Welded Rail Joints

on

Stresses in Weld Metal on Base Seams of Welded Rail Joints

The stresses at various places in the weld metal of rail joint 7-3 were measured with telemeters by Mr. O. S. Peters of the Bureau of Standards and reported by him to the Committee on Welded Rail Joints, under date of September 28, 1927. These observations were made with telemeters having 2 and 8 in. gage lengths.

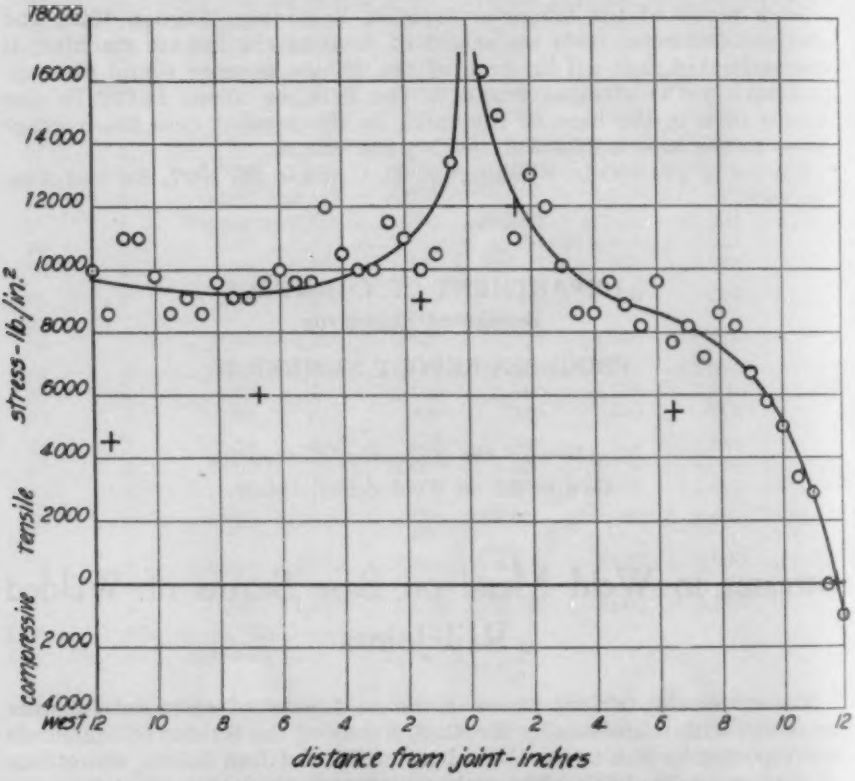
In order to investigate this problem further, the Executive Committee, Committee on Welded Rail Joints, at their meeting at the Bureau of Standards on May 14, 1928, requested Prof. Whittemore to explore the base seams of this rail with Huggenberger tensometers having a half-inch gage length.

This work has now been completed as well as similar stress determinations on another and untested rail joint, 15-33.

The rails were supported on a span of 52 in. and load was applied at the joint (at the center of the span). Half-inch gage lengths were laid off along the entire length of the base seams and four Huggenberger tensometers were attached at four gage lengths. Readings were taken, the load applied and final readings were taken. The load was then re-

leased and the tensometers moved to other gage lines until the strains had been measured in all the gage lines.

One division on the tensometers amounted to about 0.0009 in. On a ½-in. gage length on material having an assumed modulus of elasticity of 29,000,000 lb./in.², one division would correspond to a stress of about



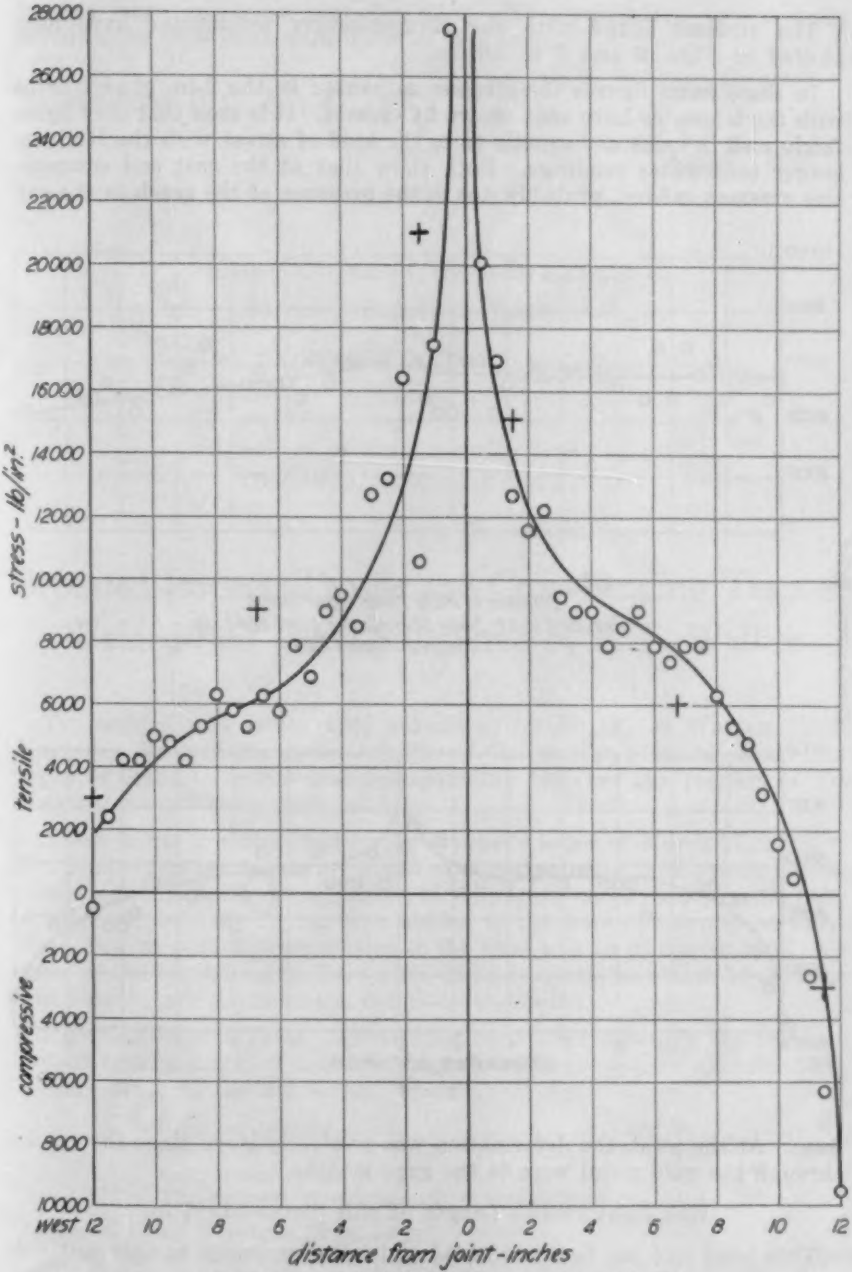
Stresses in Weld-Metal, Base Seam, Head Side
Rail Joint 7-3; Span 52 in; Center Load 30,000 lb
Progress Report No. 27

FIG. 6

5200 lb./in.². Readings were estimated to one-tenth of a division, corresponding to a stress of about 500 lb./in.².

Rail Joint 7-3. Length of side plates—26 in.

This joint had previously been used by Mr. O. S. Peters. Stresses at various points were reported by him under date of September 28, 1927. At the start of the tests reported in this progress report, there were visible cracks across the base seam weld metal at the joint. There was also a crack in the base of the rail at the east end of the weld, lip side. A load of 30,000 lb. was used for this test.



Stresses in Weld Metal, Base Seam, Lip Side
Rail Joint T-3; Span 52 in.; Center Load 30,000 lb.
Progress Report No. 27

FIG. 7

The stresses found with the Huggenberger tensometer have been plotted in Figs. 6 and 7 as circles.

In these same figures the stresses measured in the 2-in. gage lengths with the telemeter have been shown by crosses. It is seen that they agree fairly well in value and exactly as to the kind of stress with the Huggenberger tensometer readings. Both show that at the east end compressive stresses existed, probably due to the presence of the crack in the rail

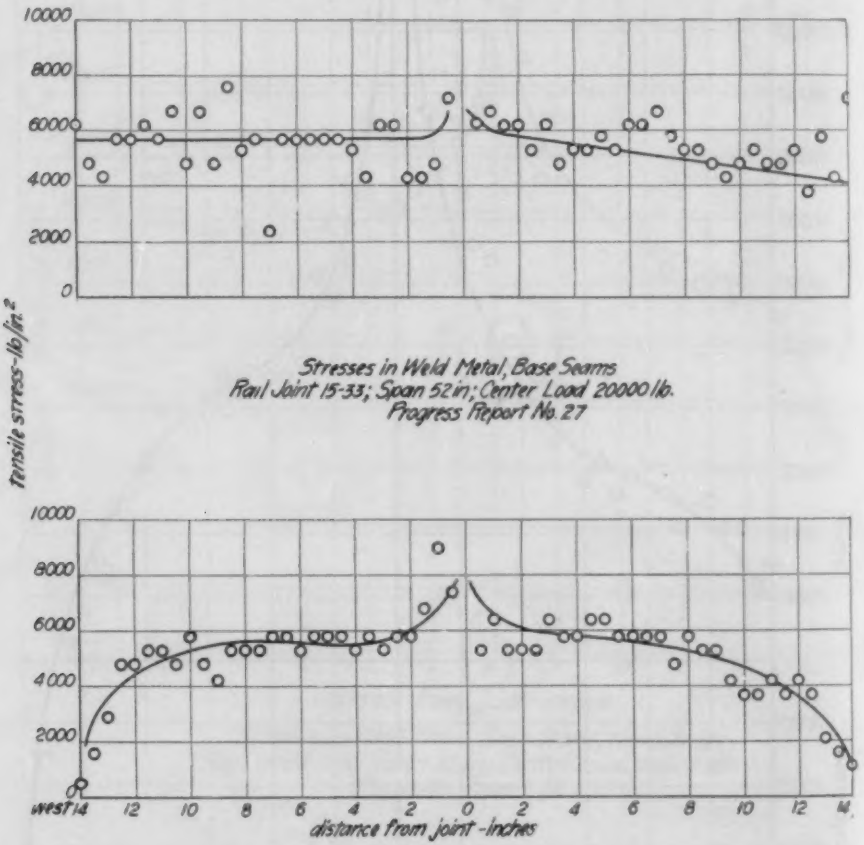


FIG. 8

base. At the joint, the deformation was relatively large since the cracks through the weld metal were in the gage lengths.

Rail Joint 15-33. Length of side plates—29¼ in.

This joint had not been subjected to loading previous to this test. A load of 20,000 lb. was used in order not to overstress the material. Fine cracks across the weld metal at the joint developed during the loading. The stresses have been plotted in Fig. 8. They are fairly constant except

for the large extension over the joint. No compressive strains were found in the base seam weld metal of this joint.

GEORGE K. BURGESS, *Director.*

Washington, D. C., Aug. 27, 1928.

Aug. 27, 1928.

DEPARTMENT OF COMMERCE
Bureau of Standards, Washington

PROGRESS REPORT NO. 23

to

Members of the Executive Committee
Committee on Welded Rail Joints

on

Repeated Impact, Tensile and Cross-bending Tests of Welded Rail Joints Submitted by F. B. Walker

Ten welded rail joints were submitted by Mr. F. B. Walker, Chief Engineer, Eastern Massachusetts Street Railway Co., Boston, Mass., for repeated impact, tensile and cross-bending tests at the request of the Committee on Welded Rail Joints.

These joints are described in Mr. Walker's letter of March 27, 1928, to Mr. Spraragen and details are given on the drawing of the Eastern Massachusetts Street Railway Co., Maint. of Way Dept. dated February 29, 1928. A plate, ¾ by 7 by 28 in., was welded to the base of the rail sections. Bars, 1½ in. square, were welded to the head and lip of the sections. On some of the specimens the bars were 28 in. long and on others 16 in. long. The lengths are listed in the detailed description.

Repeated Impact Tests. These specimens were tested in the repeated impact testing machine under the same conditions as were used for "The present state of the art series" namely,

Hammer weight	400 lb.
Height of drop	6 in.
Supporting span	22 in.

The hammer struck one rail 2 inches from the joint.

Specimen 17–1. Top bars 28 in. long.

Upper bar on head side broke loose at	18,100 blows
Upper bar on lip side broke loose at	29,300 blows
Base plate broke under non-impact rail 8 inches from joint at.	86,900 blows
Total number to cause failure	86,900 blows

Specimen 17–2. Top bars 28 in. long.

Upper bar on head side broke loose at	22,900 blows
Upper bar on lip side broke loose at	29,400 blows
Base plate broke under non-impact rail 8 inches from joint at.	74,800 blows
Total number to cause failure	74,800 blows

Specimen 17–3. Top bars 28 in. long.

Upper bar on lip side broke off at	7,000 blows
Upper bar on head side broke off at	31,200 blows

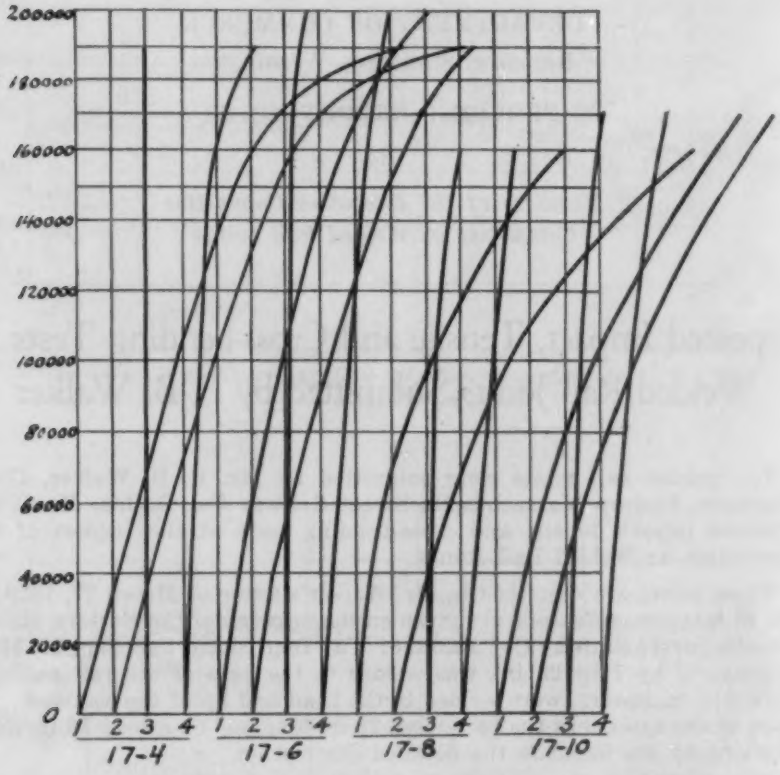


FIG. 9—TENSILE TESTS. SCALE OF EXTENSION IN 20": 1" HORIZONTAL=4 DIVISIONS=.02" EXTENSION. SMALL NUMBERS 1-2-3-4 REFER TO INDIVIDUAL EXTENSOMETERS: NO. 1 ON LIP BASE; NO. 2 ON LIP TOP; NO. 3 ON HEAD TOP; NO. 4 ON HEAD BASE

Base plate cracked under non-impact rail 7 inches from joint at	93,100 blows
Total number to cause failure	108,900 blows

Tensile Tests. Four specimens were tested in tension in the large Emery testing machine. Extensometer readings over a 20-in. gage length were taken at the four corners of the rail. The load-extension curves for these tests are given on the attached blueprint, entitled "Tensile Tests of Welded Rail Joints." The maximum loads were as follows:

Specimen	Length of Top Bars, In.	Maximum Load, Lb.
17–4	28	395,000
17–6	28	319,000
17–8	16	306,000
17–10	16	256,000

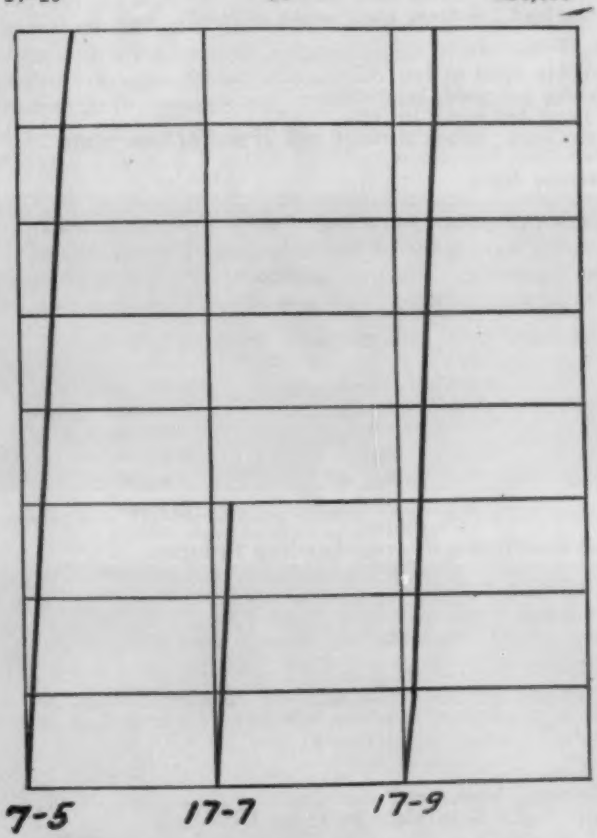


FIG. 10—BEND TESTS OF JOINTS 17-5, 17-7, 17-9 HORIZONTAL SCALE 1″=0.5″ DEFLECTION=1 DIV. VERTICAL SCALE: 1″=40,000 LBS. LOAD=2 DIV.

Detailed description of tensile failures.

Specimen 17–4.
Joint visibly opened at top ..... 40,000 lb.
Crack in transverse weld at joint, head side base..... 190,000 lb.
Crack in transverse weld at joint, lip side base ..... 232,000 lb.
Indication of yield near joint in top seams..... 384,000 lb.
Maximum load ..... 395,000 lb.
Break through rail at end of welded plates.

Specimen 17–6.
Joint visibly opened at top ..... 40,000 lb.
Crack in weld at top, both sides, near joint ..... 251,000 lb.
Crack in lower transverse welds at joint ..... 288,000 lb.
Maximum load ..... 319,000 lb.
Break through rail at end of welded plates.

Specimen 17–8.

Joint visibly open at top ..... 40,000 lb.
Crack in top head seam .....199,000 lb.
Crack in top lip seams .....214,000 lb.
Complete failure top seams on one end .....252,000 lb.
Cracks in bottom seams near joint .....267,000 lb.
Maximum load. Bottom plate broke at joint.....306,000 lb.

Specimen 17–10.

Joint visibly open at top ..... 40,000 lb.
Crack along top weld, head side .....200,000 lb.
Crack along top weld, lip side .....221,000 lb.
Maximum load. Break through rail at end of base plate.....256,000 lb.

Cross bending tests.

The three rail joints were tested on a 40-in. span with a central load. Measurements were made of the deflection of the center of the beam relative to the supports. The load-deflection curves are given on the accompanying blueprint entitled "Cross bend tests, welded rail joints."

The maximum loads and moments were as follows:

Specimen	Length of Top Bars, Inch	Maximum Central Load, Lb.	Maximum Moment, Lb.-In.
17–5	28	164,400	1,644,000
17–7	28	66,400	664,000
17–9	16	215,600	2,156,000

Detailed description of cross-bending failures.

Specimen 17–5.

Crack, bottom transverse seam, head side .....114,000 lb.
Maximum load. Tensile failure through base plate at joint....164,400 lb.

Specimen 17–7.

Failure at end of weld, base seam on lip side, through rail. Black material at first point of fracture, whether flaw in rail or included scale due to welding unable to determine.

Specimen 17–9.

Crack in weld, base, head side .....184,000 lb.
Maximum load. Base plate broke at joint .....215,600 lb.

GEORGE K. BURGESS, *Director*,

Washington, D. C., May 8, 1928.

"Walker" Type of Rail Joints

The description of the "Walker" type of rail joints and data furnished by Mr. Walker of the Eastern Massachusetts Street Railway Company in the preparation and welding of these joints are given below in a letter. This is followed by the Bureau of Standards report on tensile, repeated impact and bend tests of these joints.

March 27, 1928.

Mr. W. Spraragen, Secretary,
Committee on Welded Rail Joints,
New York, New York.
Dear Sir:

Following is a description of the manner in which we welded the ten welded rail joints which we recently shipped to the Bureau of Standards:

Total length of joints—42 in.
Kind of rail—122 lb., section 467, 7 in. girder, Class B.
Base Plates—¾ in. x 7 in. x 28 in., machine steel.
Head Bars—All 1½ in. x 1½ in.; 7 of the joints had head bars 28 in.

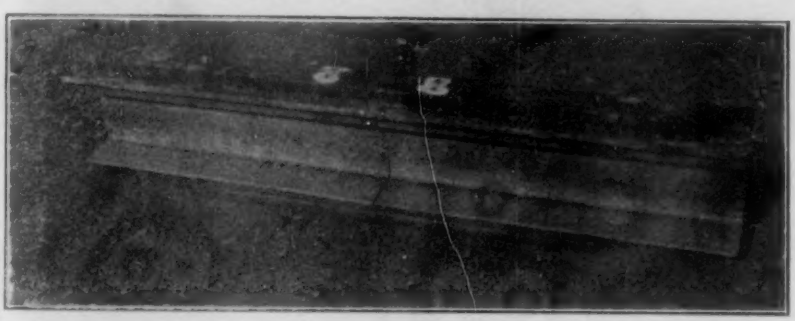


FIG. 11—THE ABUTTING RAIL ENDS FIRST WELDED TO ¾" X 7" X 28" BASE PLATE. 7"-122" RAIL LENGTH OF JOINT 42"

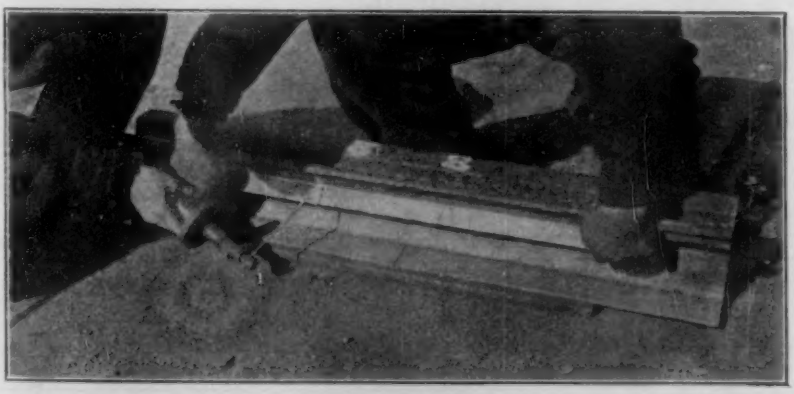


FIG. 12—WELDER'S HELPER HOLDS 1½" X 1½" X 28" HEAD BAR IN PLACE UNTIL "TACK" WELDED TO RAIL

long and three of the joints had head bars 16 in. long; all machined steel.

Weight of the base plates—41 lb. each.
Weight of the two 28 in. head bars—36 lb.
Weight of the two 16 in. head bars—26 lb.
Voltage across the arc—16 to 18.
Amperes—155.

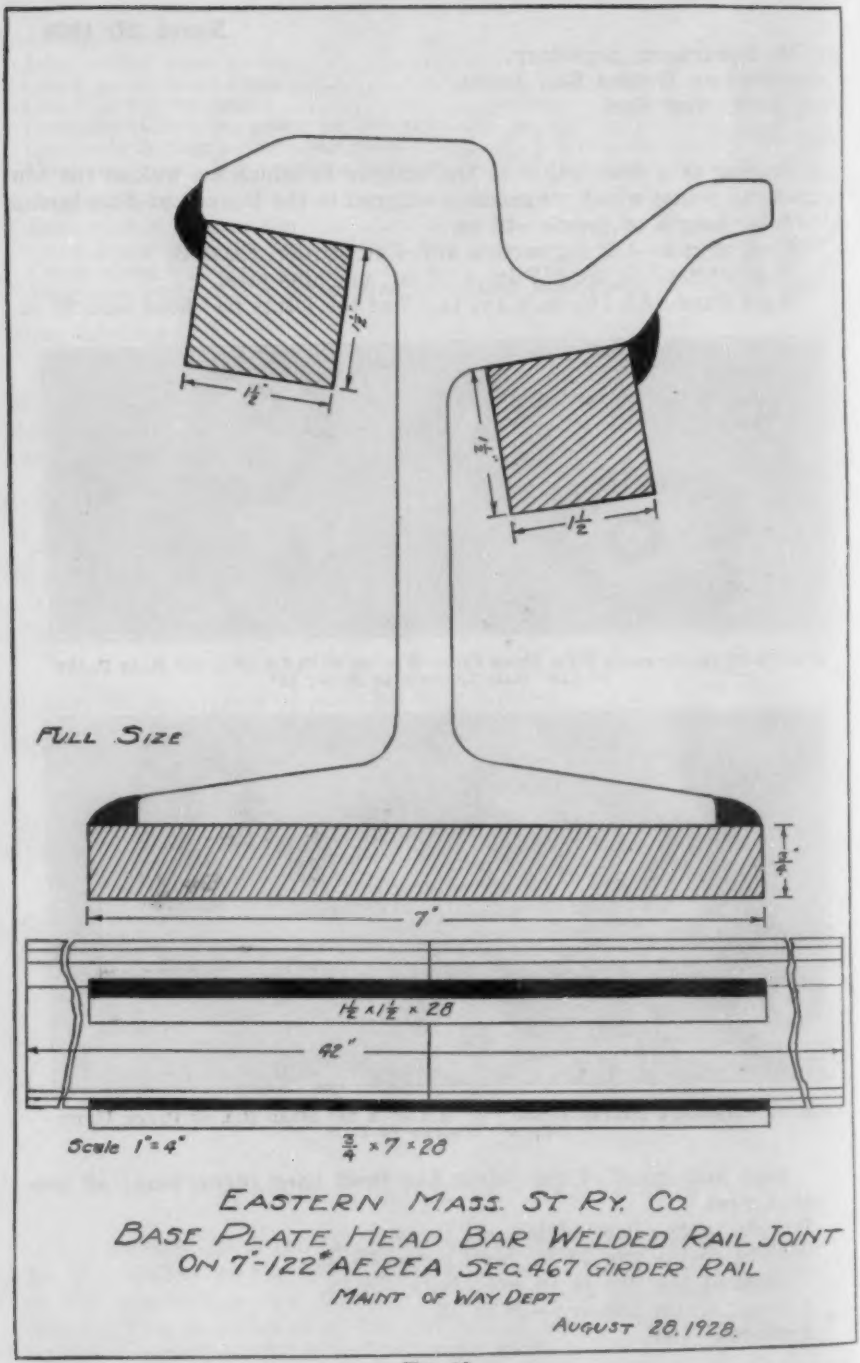

1½"
1½"
1½"
FULL SIZE
7"
1½ x 1½ x 28
42"
Scale 1"=4"
¾ x 7 x 28
EASTERN MASS. ST RY. CO.
BASE PLATE HEAD BAR WELDED RAIL JOINT
ON 7"-122# AEREA SEC. 467 GIRDER RAIL
MAINT OF WAY DEPT
AUGUST 28, 1928.

FIG. 13

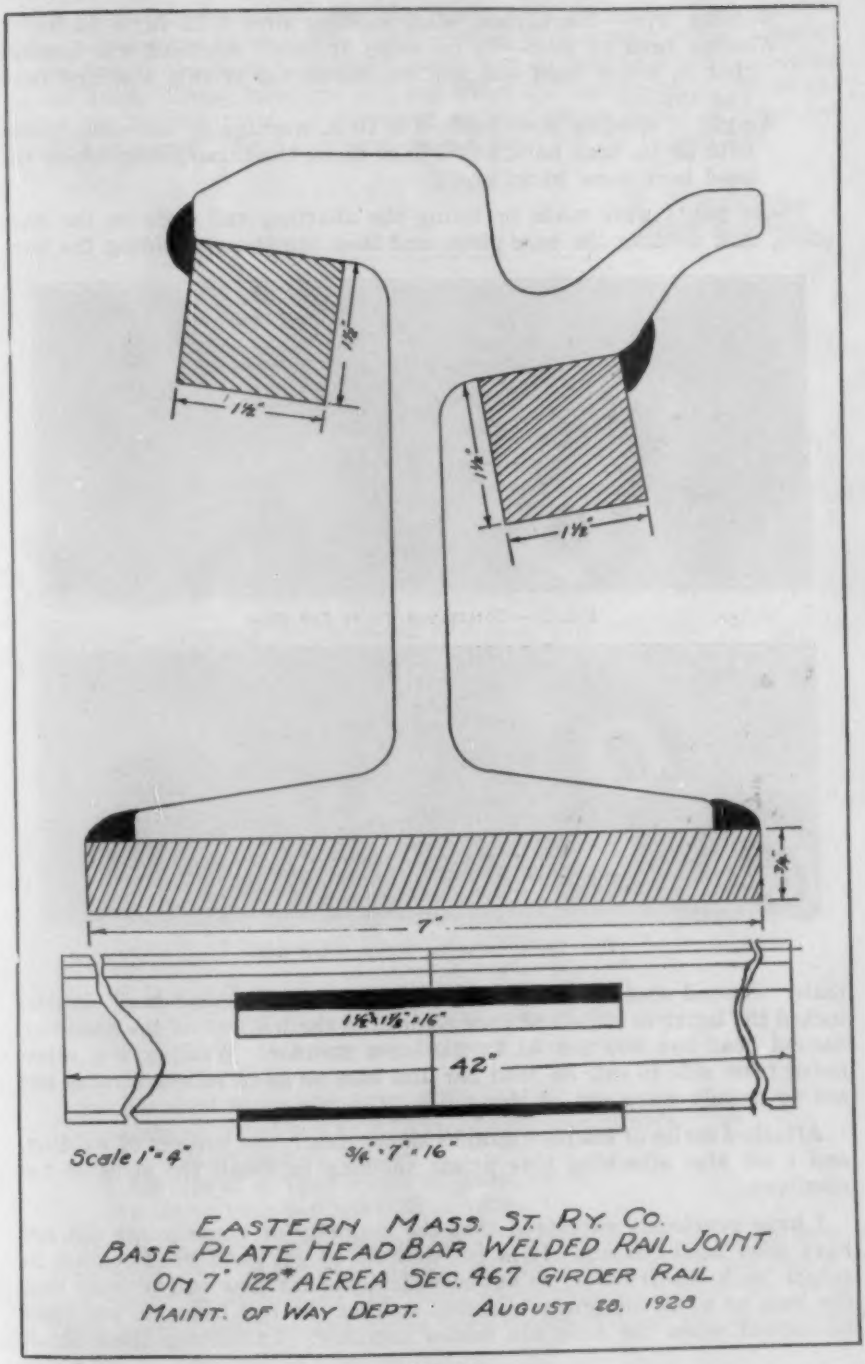

1½"
1½"
1½"
1½"
7"
1½"×1⅛"×16"
42"
¾"×7"×16"
Scale 1"=4"
EASTERN MASS. ST. RY. CO.
BASE PLATE HEAD BAR WELDED RAIL JOINT
ON 7" 122# AEREA SEC. 467 GIRDER RAIL
MAINT. OF WAY DEPT. AUGUST 28, 1928

FIG. 14

Welding wire—low carbon seam welding wire 5/32 in. x 14 in.
Welding bead of fillet—¼ in. more or less. All bead was double; that is, single bead was laid on and on top of this a second bead was applied.
Weight of welding steel used—4 3/10 lb. average on the seven joints with 28 in. head bars, and 3 6/10 lb. on the three joints where the head bars were 16 in.

These joints were made by lining the abutting rail ends on the base plate, tack welding the base plate, and then completely welding the base

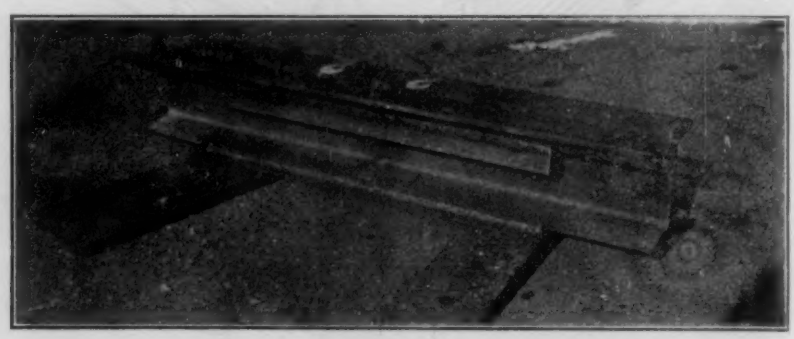


FIG. 15—COMPLETED JOINT LIP SIDE

FIG. 16—COMPLETED JOINT HEAD SIDE

plate. Second stage was for the helper to hold the head bar. Welder tacked the latter in place and then completed the welding of the head bar. Second head bar was put on in the same manner. Welding was alternated from side to side on head bar and base so as to relieve strains and not to unduly warp out of line.

Attached series of six photographs shows clearly the process of welding, and I am also attaching blue prints showing in detail the sizes of the members.

I have previously explained that the majority of these joints did not have good head contact. It is not difficult to get good head contact in actual track construction, as our specifications for new rail provide that the base be undercut proper distance so that the rail bases do not come in contact when the rails are butted together. In cutting these small

pieces, however, we found after the joints were assembled that the saw made a wider cut through the thick portion of the head, which resulted in the lips or the bases being in contact, and so leaving a slight opening at the head. These openings will not affect the tensile tests, but might affect the impact tests. I therefore selected three joints which I believed had partial, if not complete, head contact for the impact test.

Yours truly,

F. B. WALKER,
Chief Engineer.

Report by Una Welding & Bonding Co.
of

Repeated Impact Tests of Rail Joints

Submitted by

United Railways & Electric Company of Baltimore, Md.

1. The following description of the test joints referred to in this report is taken from the letter dated May 18, 1927, from Mr. W. W. Wysor to Mr. R. B. Fehr:

Memorandum of Joints Welded for Testing by The Una Welding and Bonding Company of Cleveland in Connection with the Work of the Committee on Welded Rail Joints.

Four Joints

See Mr. Ryder's letter of April 16th.
Rail Sec. B. S. Co. 122-407 A.
Joint Plates, standard rolled plate as made by the Bethlehem Steel Company and used by the Boston Elevated Railway, United Railways of Baltimore, and others.
Length of Plates, 24 inches.
Length overall of welded joints, 32 inches.
Base plates, none.
Length of top seam, 16 inches single welded with
10 inches double welded.
Base seams 2-8-inch single welded seams with
5 inches in the center doubled welded
6 inches gap between base seams.
Amperes, 195.
Kilowatt hours per joint, 8.755.
Rate of travel of arc, 3.25 in. of seam per minute.
Length of arc, 3/8 inches.
Amount of rod per 1-inch of seam, 1.6 in.
Welding time per joint, 32 minutes.

The joint plates were planed off at the top about 1/8 of an inch, so that when the joints were assembled the plates would not touch the rail head. In assembling the joints we attempted to place the plates in their normal position and shims 7/64 inches in thickness were inserted

temporarily between the top of the plates and the underside of rail head. Rails were then drawn together by drift bolts in accordance with our standard practice. After the bottom seams were welded the shims at the top were removed so that there is no contact between rail head and joint plate except through the welded metal.

2. Copies of the original data sheets are attached to the reports. A brief description of the joint and the manner of testing is given in the upper left-hand corner of each data sheet. In recording the observations the location of seam cracks was noted as follows: Each seam was divided into two parts—north (N) and south (S) of the gap. The ball of the rail was on the left side (L) and the lip was on the right side (R). Under the column "Fish Plate Cracks," the letters L and R were used to designate the left and right sides of the joint. Considering Joint R-137, for an example, at 77,100 blows, 3 inches of seam cracking were observed in the head seam on the left or ball side of the joint north of the gap. Five inches of seam cracking were also observed in the base seam on the right or lip side of the joint south of the gap.

3. Four joints prepared according to the above description were tested in a ½ in. leather pad resting on a solid steel anvil. Two of the joints (R-135 and R-136) were tested under a 236-lb. hammer dropping 10 inches and delivering an equivalent free-falling blow of 122 ft.-lb. Joints R-137 and R-138 were tested with the same hammer dropping 6 inches and delivering an equivalent free-falling blow of 61 ft.-lb.

4. The summary of results gives the important data in connection with these tests (see Series A). For comparison, the results of repeated impact tests of joints R-98 to R-101, inclusive, are added. (See Series B). This latter series of joints was submitted for test by the United Railways of Baltimore and a report was rendered December 23, 1925. Joints of the series R-98 to R-101 were similar in every essential respect, as to construction and preparation, to joints R-135 to R-138, excepting that in the former series of tests standard fish-plates were used, whereas in the latter series the fish-plates were machined away so as to make no fishing contact with the ball and lip of the rail.

Joints R-98 and R-101 were tested under a 122 ft.-lb. blow and joints R-99 and R-100 were tested under a 45.3 ft.-lb. blow. Joints R-98 and R-99 were tested on a 60-in. span support and joints R-100 and R-101 were short 32 in. joints, tested on a ½ in. leather pad resting on a solid steel anvil.

Referring to joint R-101 on the summary sheet, seam cracks were first observed at 45,000 blows. At 50,000 (50 M) blows there was 1 in. (total) of seam cracking observed and at 100,000 blows there was a total of 8½ in. of cracking. The test was discontinued before 200,000 blows were struck and this is indicated by the parentheses around the figure 17 in the sixth column. The eighth column shows that there was 20 per cent joint failure in the fish-plates at 101,000 blows. The method of obtaining this figure is explained in the foot-note. Plate cracks were observed in the wide plate at 73,600 blows and in the narrow or lip side plate at 102,800 blows. The energy of the blow was 122 ft.-lb. The joint rested on a ½- in. leather pad resting on a solid steel anvil. No rail cracks were observed.

5. *Discussion of Results:*

Failure of the joints of Series A, in which the fish-plates were machined away ⅛ in. at the rail head, occurred in the seam welds in each case. By reducing the energy of the blow from 122 to 61 ft.-lb., the number of hammer blows at which seam failure was first observed was increased from 9700 to 75,250. The rate of seam failure was likewise decreased with the lighter blow. Plate failures were not obtained in any case.

Joint R-101 of Series B (made up with standard fish-plates) was tested under a 122 ft.-lb. blow and developed very little seam cracking but failed in both fish plates.

Joint R-100, tested under a 45.3 ft.-lb. blow, also developed plate failures and very little seam cracking. The number of blows at which initial plate failure was observed was increased from 73,600 to 672,400 by reducing the energy of the blow from 122 to 45.3 ft.-lb.

The early seam failure resulting in Joint R-98 was attributed, in the report of December 23, 1925, to somewhat lighter welds and inferior fishing, combined with the rather high rate of arc travel used in the preparation of this series of joints.

Editor's Note: Tables showing progress of failure in individual joints have been omitted. The results are summarized in table of "Summary of Repeated Impact Tests."

SUMMARY OF REPEATED IMPACT TESTS

SERIES-A—Joints With Fish-Plates Machined Away ⅛ In. at the Rail Head

Our No.	Your No.	Seam Weld Cracks in Fish-Plates Started	50 M	100 M	200 M	Total	*Av. No. Blows 20 Per Cent Joint Failure	Plate Cracks Started Wide L	Narrow R	Ft.-Lb. per Blow	Span Inches	Rail Cracks Started
R-135	1	14,000	22	(55)	..	55	40,500 S	0	0	122	0	0
R-136	2	5,400	27	48	54	54	22,000 S	0	0	122	0	0
Average		9,700	24.5	(51.5)	..	54.5	31,250	0	0	122	0	0
R-137	3	34,800	4	14	40	56	91,600 S	0	0	61	0	0
R-138	4	115,700	0	0	29	(29)	132,300 S	0	0	61	0	0
Average		75,250	2	7	35	43	111,950	0	0	61	0	0
SERIES-B—Joints With Standard Fish-Plates (Date of Report December 23, 1925)												
R-101	D	45,000	1	8.5	(17)	17	101,000 P	73,600	102,800	122	0	None
R- 98	A	1,150	(49.5)	..	..	49.5	9,100 S	.....	.....	122	60	None
R-100	C	905,500	0	0	0	3	496,700 P	672,400	475,600	45.3	0	397,500
R- 99	B	376,700	0	0	0	2	649,300 P	647,000	540,000	45.3	60	647,000

*NOTE—Av. No. Blows—20 Per Cent Joint Failure:—This figure was obtained in the following manner: The combined width of both fish-plates was taken as 9 inches. When the vertical fish-plate cracking totaled 1.8 inches the joint was considered a 20 per cent failure. In the case of rail failures 100 per cent failure of the joint was considered when the crack across the head was 5⅛ in. wide or 6 in. across the base. Twenty per cent failure was then taken when these cracks equaled 1.19 in. and 1.2 in. respectively. The total length of the fish-plate seams was taken as 100 per cent and 20 per cent failure was considered when 1/5 of the total fish-plate seams failed. In case failure developed in several members, the number of blows at which failure in one member first reached 20 per cent was taken. After each number in the above column the letters R, P, or S are used to signify that 20 per cent failure occurred in the rail, fish-plates, or seams respectively.

6. *Conclusions:*

a. The joints of Series A, having fish-plates of such design that the impact blow was transmitted directly to the seam welds, developed seam failures and no plate failure.

b. The type of failure was the same for the 122 ft.-lb. and the 61 ft.-lb. blows, though the lighter blow resulted in a decided increase in the number of blows before initial failures were observed and in a decrease in the rate of failure.

Second Report on Longitudinal Shearing Tests of Rail Plate Welds

By R. J. Fogg,

Professor of Civil Engineering, Lehigh University, July, 1928

To the Committee on Welded Rail Joints, American Bureau of Welding and A.E.R.E.A.

Gentlemen:

The following is a report on the longitudinal shearing tests of the second shipment of welded rail specimens, delivered at the Fritz Engineering Laboratory in April. These tests supplement those made in 1926; the method of testing, apparatus used, etc., being the same. The results of the former tests appeared in Progress Report Number 5 (pages 5 to 47) under date of April, 1927. The investigations have been made by M. O. Fuller under the direction of R. J. Fogg.

Type of Specimens

The thirty-two specimens were found, on delivery, to be in first-class condition. Figure 17 shows four types of specimens after they were tested, the different parts being wired into their relatively true original positions. Before testing, each plate was cut in halves at the Laboratory, lengthwise of the rail, so that for each specimen there were four pieces of plate, each piece being attached to the rail by only one seam.

Welding Data for Shear Specimens

The welding data as furnished by the Bureau of Standards is shown in the following table.

WELDING DATA

Specimen Designation	Method of Welding	Type of Plate	Time of Welding, Min.	Welding Rod Used, Lb.
C6A	Carbon arc, hand feed, 2 layers	Modified Shoulder	45.4	2.11
C6B		Modified Shoulder	49.1	2.08
C7A		Modified Boston	37.0	1.87
C7B		Modified Boston	42.3	1.85
C8A		Modified Rail Joint Co.	54.0	2.05
C8B		Modified Rail Joint Co.	53.2	2.01
C9A		Boston	47.3	1.69
C9B		Boston	45.8	1.57
I6A	Metal arc, 2 layers	Modified Shoulder	44.1	2.14
I6B		Modified Shoulder	46.4	2.01
I7A		Modified Boston	46.8	1.81
I7B		Modified Boston	44.4	2.02
I8A		Modified Rail Joint Co.	47.5	1.83
I8B		Modified Rail Joint Co.	35.1	2.07
I9A		Boston	47.2	1.75
I9B		Boston	43.6	1.78

Tabular Results

In addition to the data given in the 1927 report, a column has been added showing the strength of a linear inch of weld. Under the column heading "Appearance of Fracture" the statement "Good-Spot" means one layer of fracture is good while the other is welded only in spots. "Fair-Spot" indicates one layer fair, the other layer spotted.

Typical Fractures and Graphs

Figs. 17, 18 and upper part of 19 show *typical* fractures for each type of specimen, while lower part of Fig. 19 shows *miscellaneous* fractures, some of which are especially poor. Graphs have been plotted for each test.

Summary

Many of the Fractures (especially in the Metal Arc series) showed that the two layers of welding did not fuse together, i.e., when the joints were broken there were two distinct weld fracture layers. One of these layers would in general, be good or fair while the other was often welded in spots only. (See I specimens in lower part of Fig. 19.)

In general, the Metal Arc weld (I series) were stronger than those formed by the Carbon Arc (C series), however, the appearance of the fractures for the latter was often far better than the former.

Respectfully submitted,
R. J. FOGG.

Editor's Note: There follows the various illustrations referred to in Professor Fogg's report; the tabular results of the shear tests, chart showing comparative shear test results, load displacement diagrams of the shear tests, and etched sections of each type of joint plate and method of welding. This is given elsewhere in Fig. 1 *the dimensions of the joint plates used in this investigation.*

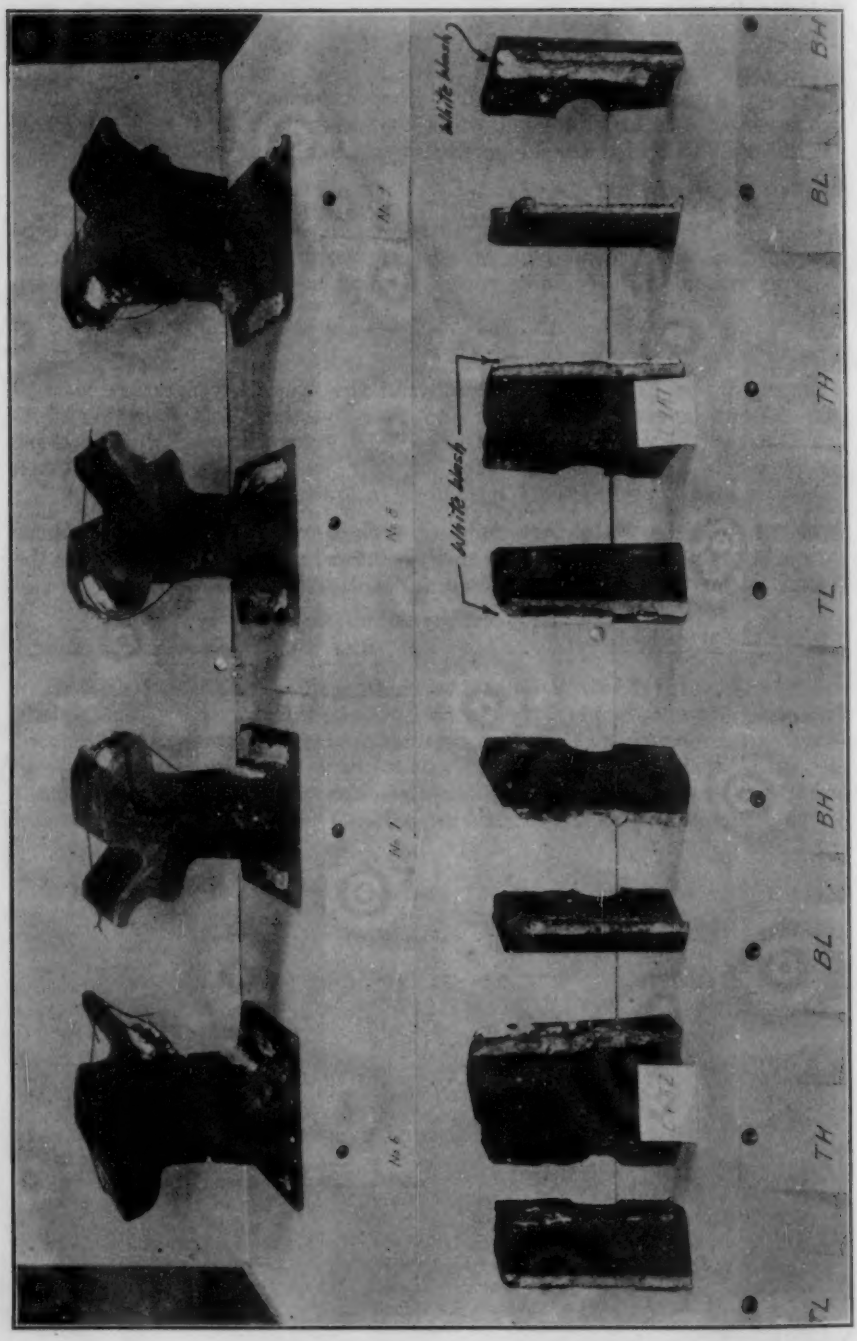

White Blank
White Blank
No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
TL
TH
BL
BH
TL
TH
BL
BH

Fig. 17

White Wash
TL
TH
BL
BH
White Wash
TL
TH
BL
BH
White Wash
TL
TH
BL
BH

FIG. 18

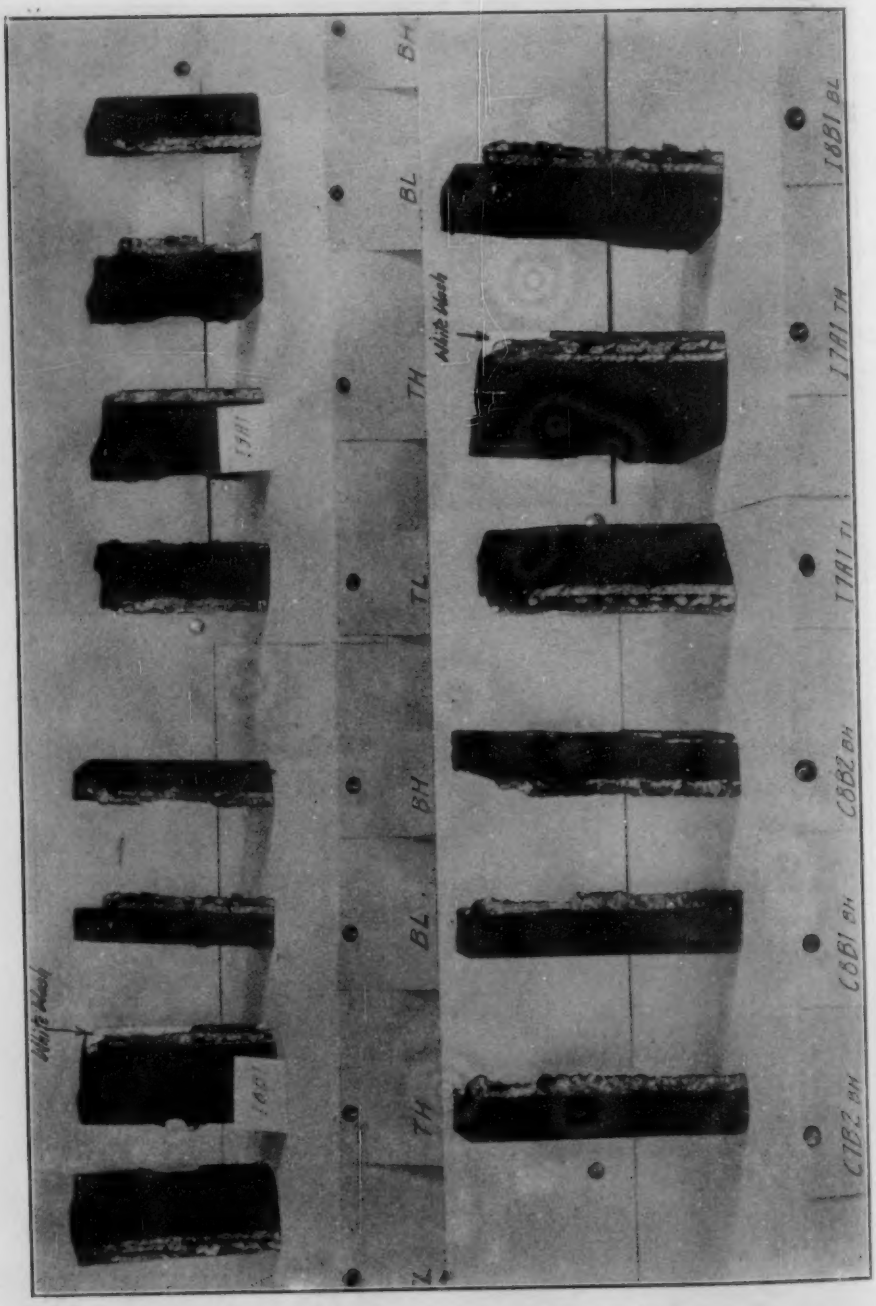
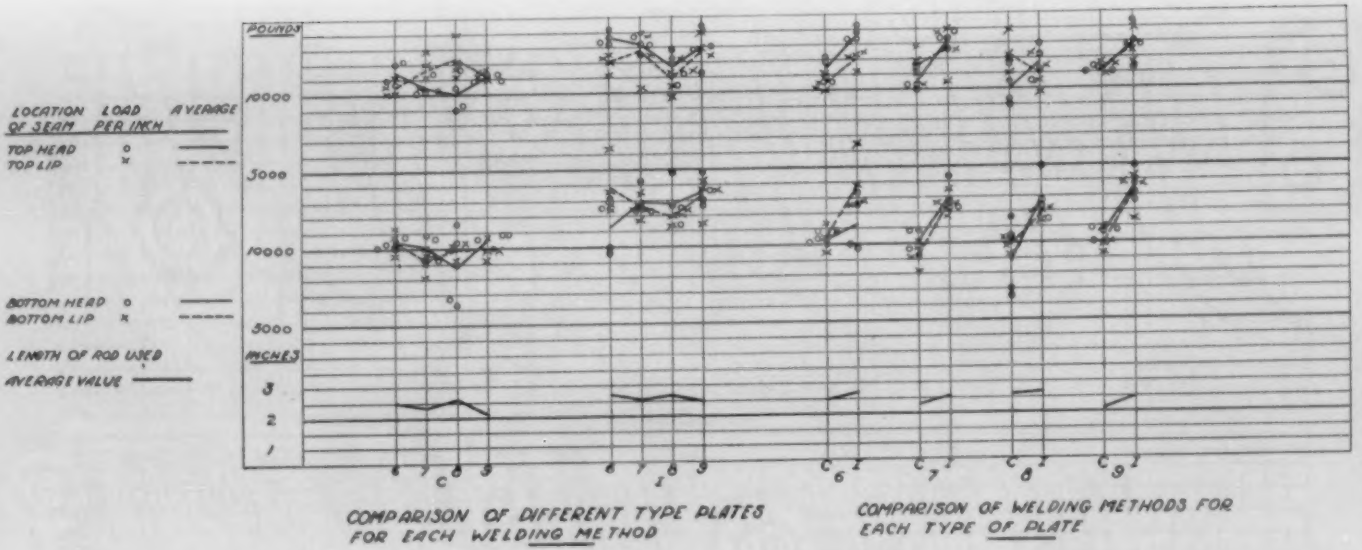

White Mark
1401
1311
TH
BL
BH
TL
White Mark
1681 BL
1741 TH
1741 TL
C682 BH
C681 BH
C782 BH

FIG. 19

Specimen	Location of Seam	Area Sq.In.	Proportional Limit Lbs.	#/Sq.In.	Maximum Load Lbs.	#/Sq.In.	Appearance of Fracture	Load at Sign of 1st Crack	Gross Length of Weld	Maximum Load/In. of Weld
C6A-1	Top-Lip	1.709	35000	20480	54920	32140	Good	42100	5.45	10075
	Top-Head	2.752	40000	14540	72600	26390	Good	46800	5.95	12200
	Base-Lip	1.378	25000	18140	48670	35315	Good	36950	4.75	10245
	Base-Head	1.553	30000	19315	45700	29425	Good	35000	4.50	10155
C6A-2	Top-Lip	1.673	35000	20920	61120	36530	Good	42000	5.50	11110
	Top-Head	2.763	40000	14475	69250	25060	Good	47600	6.30	10990
	Base-Lip	1.475	30000	20340	47480	32190	Fair	42000	5.00	9496
	Base Head	1.870	35000	18715	52500	28070	Good	43700	5.15	10195
C7A-1	Top-Lip	2.310	35000	15150	63940	27680	Good	51700	5.30	12060
	Top-Head	1.870	30000	16040	63910	34170	Good	49570	5.60	11410
	Base-Lip	1.213	26000	21430	48740	40160	Good	41260	4.85	10045
	Base-Head	1.439	30000	20850	54650	37975	Good	39320	5.05	10820
C7A-2	Top-Lip	1.649	39000	21090	67170	36330	Good	51230	5.20	12920
	Top-Head	1.581	35000	22140	54850	34690	Good	43400	5.35	10250
	Base-Lip	1.275	35000	27450	48370	37940	Fair	41750	5.00	9674
	Base-Head	1.340	25000	18655	51070	38110	Good	37000	4.70	10865
C8A-1	Top-Lip	2.286	47500	20780	74530	32605	Good	61500	5.35	13930
	Top-Head	1.670	35000	20955	61000	36525	Good	46550	5.25	11620
	Base-Lip	1.342	30000	22355	48835	36385	Good	41420	5.25	9300
	Base-Head	1.240	30000	24190	52230	42120	Good	33700	4.50	11610
C8A-2	Top-Lip	2.028	35000	17260	62390	30765	Fair	47370	5.25	11860
	Top-Head	1.472	39000	26490	56545	38410	Good	44420	5.40	10470
	Base-Lip	1.271	35000	27540	44870	35300	Good	31170	4.40	10195
	Base-Head	1.201	32500	27060	50250	41840	Good	34300	4.90	10255
C9A-1	Top-Lip	2.286	42500	18590	61570	26935	Good	28000	5.35	11510
	Top-Head	1.450	34000	23450	55770	38460	Good	40000	5.00	11154
	Base-Lip	1.300	29000	22310	49410	38010	Good	32650	5.00	9882
	Base-Head	1.446	32800	22675	52070	36010	Good	38800	4.90	10630
C9A-2	Top-Lip	1.854	35000	18800	59500	32095	Good	47400	5.10	11665
	Top-Head	1.875	39000	20800	62560	33365	Good	40600	5.50	11375
	Base-Lip	1.410	32500	23050	54550	38690	Good	42000	5.05	10800
	Base-Head	1.300	32000	24610	54380	41830	Good	36250	5.00	10876
C6B-1	Top-Lip	1.841	40000	21730	64460	35010	Good	55000	6.30	10230
	Top-Head	2.872	37500	13060	80350	27980	Good	54000	6.70	11990
	Base-Lip	1.545	30000	19420	58670	37975	Good	40000	5.15	11395
	Base-Head	1.563	30000	19195	58200	37240	Good	38300	5.55	10485
C6B-2	Top-Lip	1.720	37500	21800	61130	35540	Good	45000	5.80	10540
	Top-Head	2.680	25000	93280	67360	25145	Good	53350	6.30	10610
	Base-Lip	1.555	25000	16075	56420	36250	Good	38700	5.25	10745
	Base-Head	1.543	30000	19440	54400	35250	Good	37350	5.05	10770
C7B-1	Top-Lip	1.951	40000	20500	63800	32700	Good	52550	6.15	10375
	Top-Head	1.750	37000	21140	61860	35345	Good	50000	6.00	10310
	Base-Lip	1.330	27500	20675	47040	35370	Fair	32150	5.70	8253
	Base-Head	1.531	29000	18940	52150	34060	Good	37600	5.65	9230
C7B-2	Top-Lip	1.750	37500	21430	67750	38720	Good	52900	6.15	11015
	Top-Head	1.861	30000	16120	65760	35350	Good	54250	6.45	10200
	Base-Lip	1.342	32000	23845	51240	38180	Good	40000	5.65	9070
	Base-Head	1.760	27000	15340	58720	33360	Good	36200	6.10	9626
C8B-1	Top-Lip	2.770	40000	14440	72700	26250	Good	10000	6.55	11100
	Top-Head	1.643	35000	21300	51760	31500	Good	41820	5.80	8924
	Base-Lip	1.585	32500	20505	60950	38450	Good	20000	5.85	10420
	Base-Head	0.756	25000	32980	36300	47690	Poor-Spot	36300	5.25	6914
C8B-2	Top-Lip	2.420	37500	15495	73780	30490	Good	54350	6.05	12195
	Top-Head	1.910	35000	18325	58180	30460	Good	44250	6.25	9308
	Base-Lip	1.549	25000	16140	58250	37605	Good	47000	5.90	9874
	Base-Head	1.060	24000	22660	37580	35790	Poor	27700	5.85	6424
C9B-1	Top-Lip	1.902	40000	21030	59810	31445	Good	52700	5.50	10875
	Top-Head	1.833	40000	21820	60400	32950	Good	42700	5.50	10980
	Base-Lip	1.421	32500	22870	51270	36080	Good	35000	5.50	9320
	Base-Head	1.586	36000	23440	55160	35910	Good	47100	5.50	10030
C9B-2	Top-Lip	1.960	35000	17860	64310	32810	Good	48200	5.75	11185
	Top-Head	1.901	42500	22355	63800	33560	Good	42800	5.85	10900
	Base-Lip	1.436	30000	20890	56180	39080	Good	37150	5.65	9933
	Base-Head	1.682	40000	23780	63140	37540	Good	28900	5.85	10790

Specimen	Location of Seam	Area Sq.In.	Proportional Limit Lbs.	Proportional Limit #/Sq.In.	Maximum Load Lbs.	Maximum Load #/Sq.In.	Appearance of Fracture	Load at Sign of 1st Crack	Gross Length of Weld	Maximum Load/In of Weld
I6A-1	Top-Lip	1.873	40000	21355	60000	32030	Good	59000	5.35	11215
	Top-Head	2.500	40000	16000	73030	29230	Good	66300	5.50	13280
	Base-Lip	1.608	35000	21770	66150	41140	Good	47750	4.80	13780
	Base-Head	1.568	35000	22320	64400	41070	Good	43150	4.90	13140
I6A-2	Top-Lip	2.188	32500	14850	63460	29050	Good	58460	5.15	12320
	Top-Head	2.312	40000	17300	70820	30650	Good	64500	5.30	13360
	Base-Lip	1.625	45000	26900	74100	45600	Good	37770	4.80	15470
	Base-Head	0.955	27500	28800	49470	51800	Poor-Spot	32200	4.95	9994
I7A-1	Top-Lip	1.368	45000	32420	68250	47010	Good-Spot	27600	4.65	14030
	Top-Head	1.755	39000	22220	64720	36880	Good-Spot	44200	5.15	12565
	Base-Lip	1.225	40000	32705	58720	48010	Fair-Spot	51580	4.70	12490
	Base-Head	1.289	35000	27150	57970	44970	Good-Spot	40000	4.70	12330
I7A-2	Top-Lip	1.766	35000	19820	54970	31125	Fair	52100	5.25	10470
	Top-Head	1.899	40000	21060	70880	37320	Good	50000	5.35	13250
	Base-Lip	1.540	37000	24030	59600	38700	Fair	44150	5.05	11800
	Base-Head	1.663	35000	21048	60430	36338	Good	41650	4.75	12720
I8A-1	Top-Lip	0.932	40000	42915	49080	52630	Poor-Spot	46820	5.05	9719
	Top-Head	1.363	50000	36680	66710	48940	Good	48200	5.45	12240
	Base-Lip	1.104	30000	27175	54700	49545	Fair-Spot	49150	4.80	11395
	Base-Head	1.500	42500	28330	65500	43670	Good-Spot	43000	5.15	12720
I8A-2	Top-Lip	1.239	35000	28250	53300	43020	Poor-Spot	40000	5.05	10555
	Top-Head	1.528	40000	26180	60540	39620	Good	53800	4.70	12880
	Base-Lip	1.440	30000	20830	62390	43325	Fair-Spot	45000	5.20	12000
	Base-Head	1.571	32500	20690	64750	41225	Good	45000	4.35	14880
I9A-1	Top-Lip	1.863	47500	25495	59500	31940	Good	46950	4.60	12935
	Top-Head	1.465	40000	27300	60540	41320	Good	53550	4.65	13020
	Base-Lip	1.535	40000	26060	60300	39285	Good	45000	4.25	14190
	Base-Head	1.863	37500	20130	63380	34020	Good	45000	4.60	13780
I9A-2	Top-Lip	1.857	35000	18850	58760	31640	Good	50000	4.70	12500
	Top-Head	1.887	47500	25170	73800	39110	Good	53400	5.10	14470
	Base-Lip	1.834	40000	21810	67970	37060	Good	22000	4.90	13870
	Base-Head	1.750	45000	25715	72890	41650	Good	48600	4.90	14878
I6B-1	Top Lip	1.914	45000	23510	65680	34320	Good	56850	5.40	12160
	Top-Head	2.921	47000	16090	67780	30050	Good	-----	6.15	14275
	Base-Lip	1.578	30000	19010	68110	43165	Good-Spot	33300	5.35	12730
	Base-Head	1.293	40000	30930	56200	43460	Fair-Spot	14450	5.75	9774
I6B-2	Top-Lip	2.054	45000	21910	72170	35135	Good	50000	5.80	12445
	Top-Head	2.300	50000	21740	86720	37705	Good	52580	6.30	13765
	Base-Lip	1.255	35000	27890	67880	54080	Good	35000	5.45	12455
	Base-Head	1.741	29000	16655	69380	39850	Fair-Spot	36000	5.55	12500
I7B-1	Top-Lip	2.067	55000	26610	76570	37045	Fair-Spot	53300	6.05	12655
	Top-Head	1.941	45000	23180	76180	39245	Fair-Spot	55000	5.75	13250
	Base-Lip	1.740	45000	25860	69850	40145	Fair-Spot	30000	5.55	12605
	Base-Head	1.820	42500	23350	70730	38865	Fair-Spot	37960	5.70	12410
I7B-2	Top-Lip	2.344	40000	17065	80230	34230	Good-Spot	55000	5.80	13830
	Top-Head	1.982	50000	25230	74930	37805	Good	55000	6.45	13750
	Base-Lip	1.639	30000	18300	69860	42620	Good	43000	5.15	13565
	Base-Head	1.757	35000	19920	71150	40500	Good	37400	4.95	14370
I8B-1	Top-Lip	2.242	45000	20070	71700	31980	Fair-Spot	45000	5.85	12255
	Top-Head	1.650	40000	24240	57820	35040	Fair-Spot	48300	5.50	10510
	Base-Lip	1.216	37500	30840	63580	52280	Fair-Spot	45000	5.30	11995
	Base-Head	1.619	35000	21620	63680	39335	Poor-Spot	38650	5.55	11478
I8B-2	Top-Lip	1.617	45000	27830	67600	41805	Poor-Spot	35000	5.95	11360
	Top-Head	1.430	40000	27970	66020	46170	Poor-Spot	60000	5.90	11190
	Base-Lip	1.614	35000	21685	64180	39760	Fair-Spot	30000	5.30	12110
	Base-Head	1.694	45000	26565	65140	38455	Good	52200	5.25	12410
I9B-1	Top-Lip	1.584	45000	28410	67200	42420	Good-Spot	55000	4.80	14000
	Top-Head	1.903	42500	22330	67820	35640	Good	56250	5.30	12795
	Base-Lip	1.692	47500	28070	73370	43360	Good-Spot	56000	5.35	13715
	Base-Head	2.012	40000	19880	68650	34130	Good	55000	5.40	12710
I9B-2	Top-Lip	1.433	39000	27215	61700	43055	Fair-Spot	56600	5.30	11640
	Top-Head	1.841	42500	23085	61020	33145	Fair-Spot	57800	5.40	11300
	Base-Lip	1.108	45000	40610	61940	55900	Fair-Spot	53700	5.40	11470
	Base-Head	1.773	40000	22560	68150	38435	Good	38600	5.20	13100



COMPARISON OF DIFFERENT TYPE PLATES FOR EACH WELDING METHOD

COMPARISON OF WELDING METHODS FOR EACH TYPE OF PLATE

NOTES

LENGTH OF SEAMS ABOUT FIVE INCHES, ACTUAL LENGTHS USED IN CALCULATING LOAD PER LINEAL INCH.
FIGURES GIVEN ARE FOR MAXIMUM LOADS, NOT LOADS TO YIELD POINT, OR AT POINT OF FIRST CRACK.

6, 7, 8, 9, INDICATES DIFFERENT TYPE PLATES TESTED

METHODS OF WELDING { C - INDICATES CARBON ARC. I - INDICATES METALLIC ARC.

$\frac{3}{32}$" ROD USED IN CARBON ARC PROCESS. $\frac{5}{32}$" ROD USED IN METALLIC ARC PROCESS. BUT LENGTHS OF ROD USED ARE ALL FIGURED AS EQUIVALENT TO $\frac{3}{32}$" ROD

FIG. 20

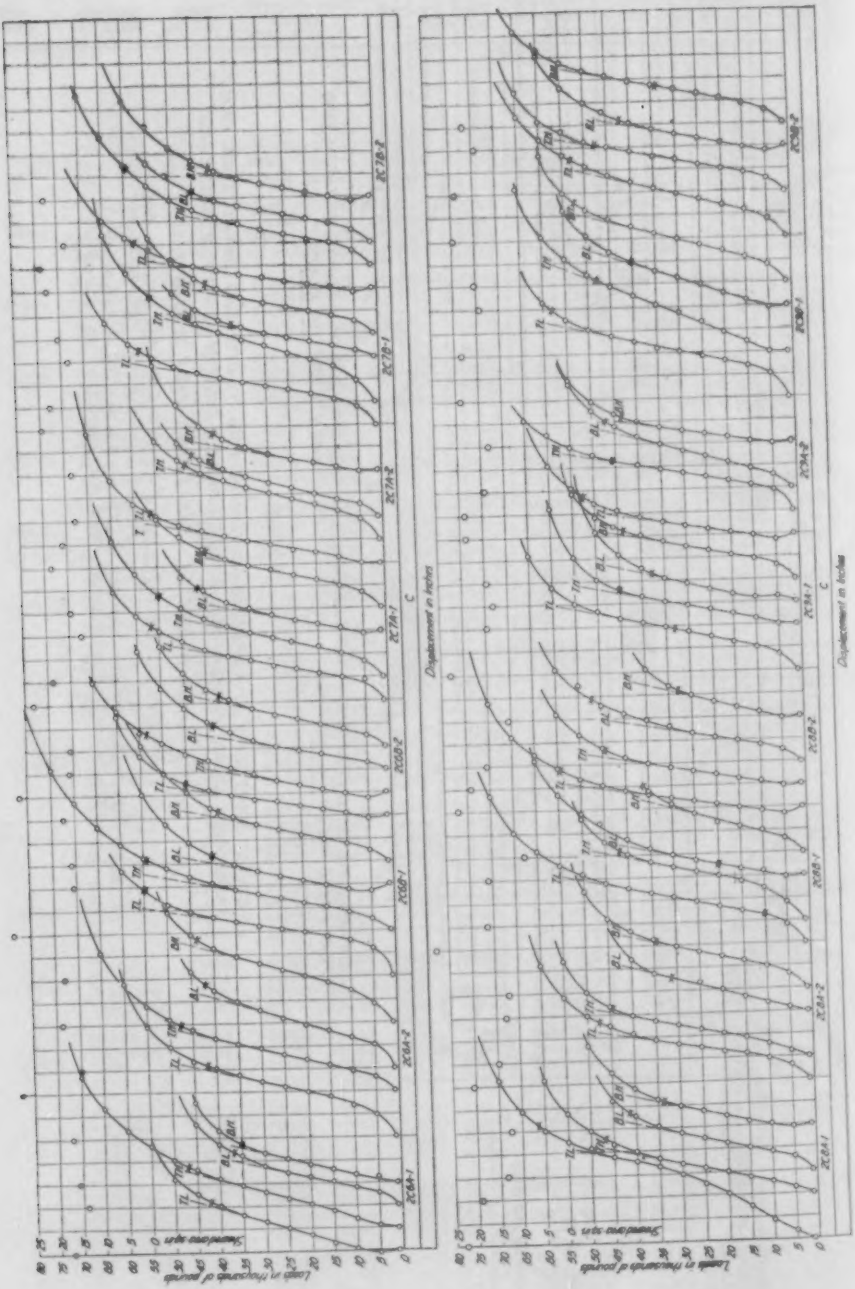


FIG. 21—LOAD DISPLACEMENT CURVES

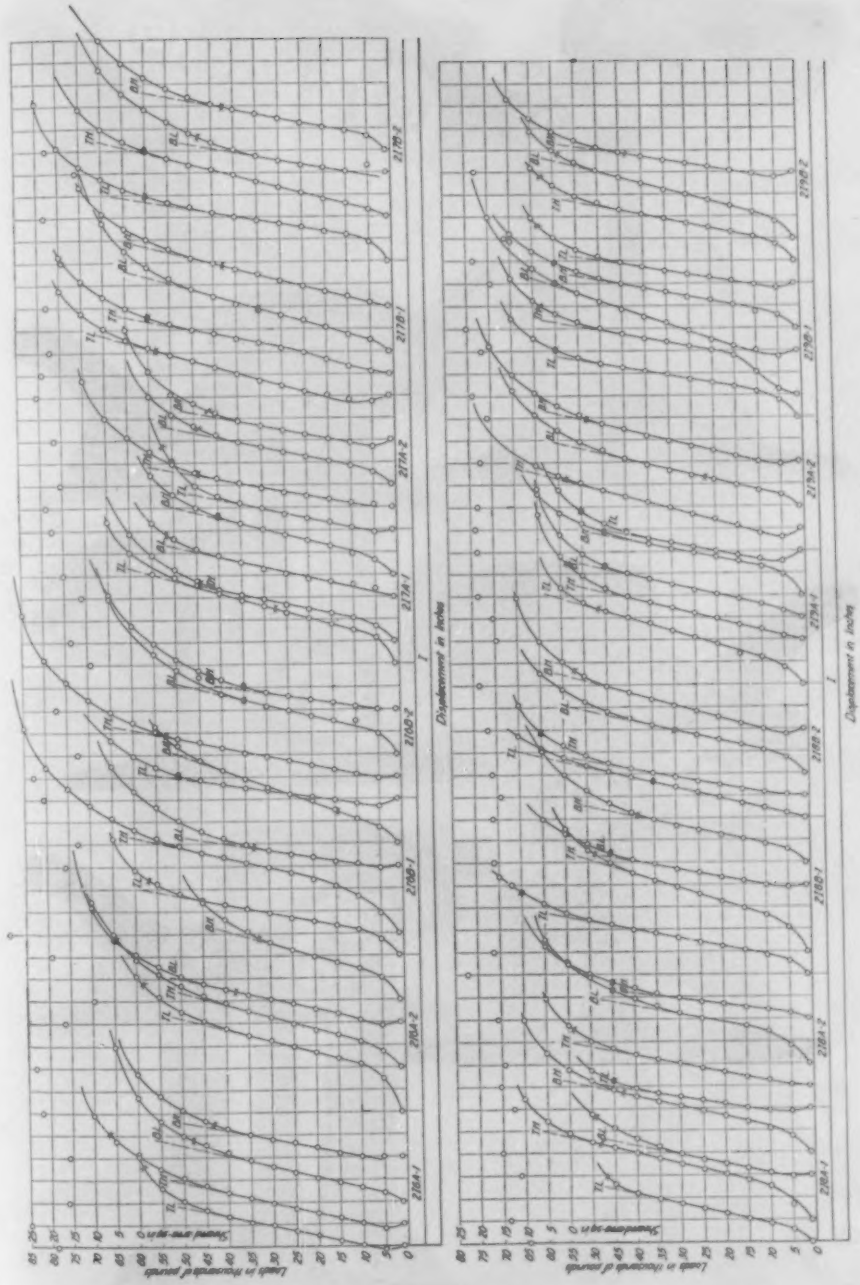


FIG. 22—LOAD DISPLACEMENT CURVES

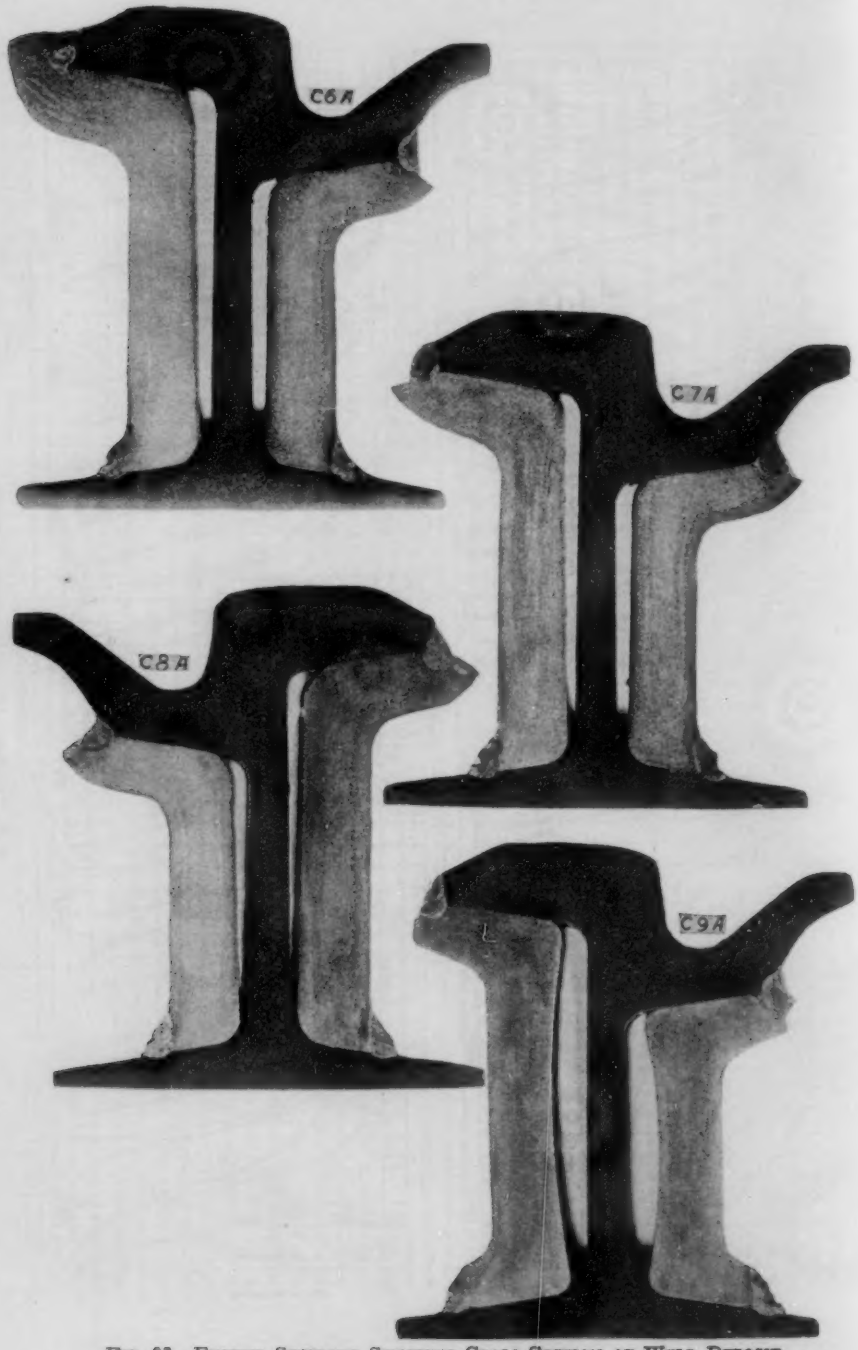


FIG. 23—ETCHED SECTIONS SHOWING CROSS SECTION OF WELD DEPOSIT

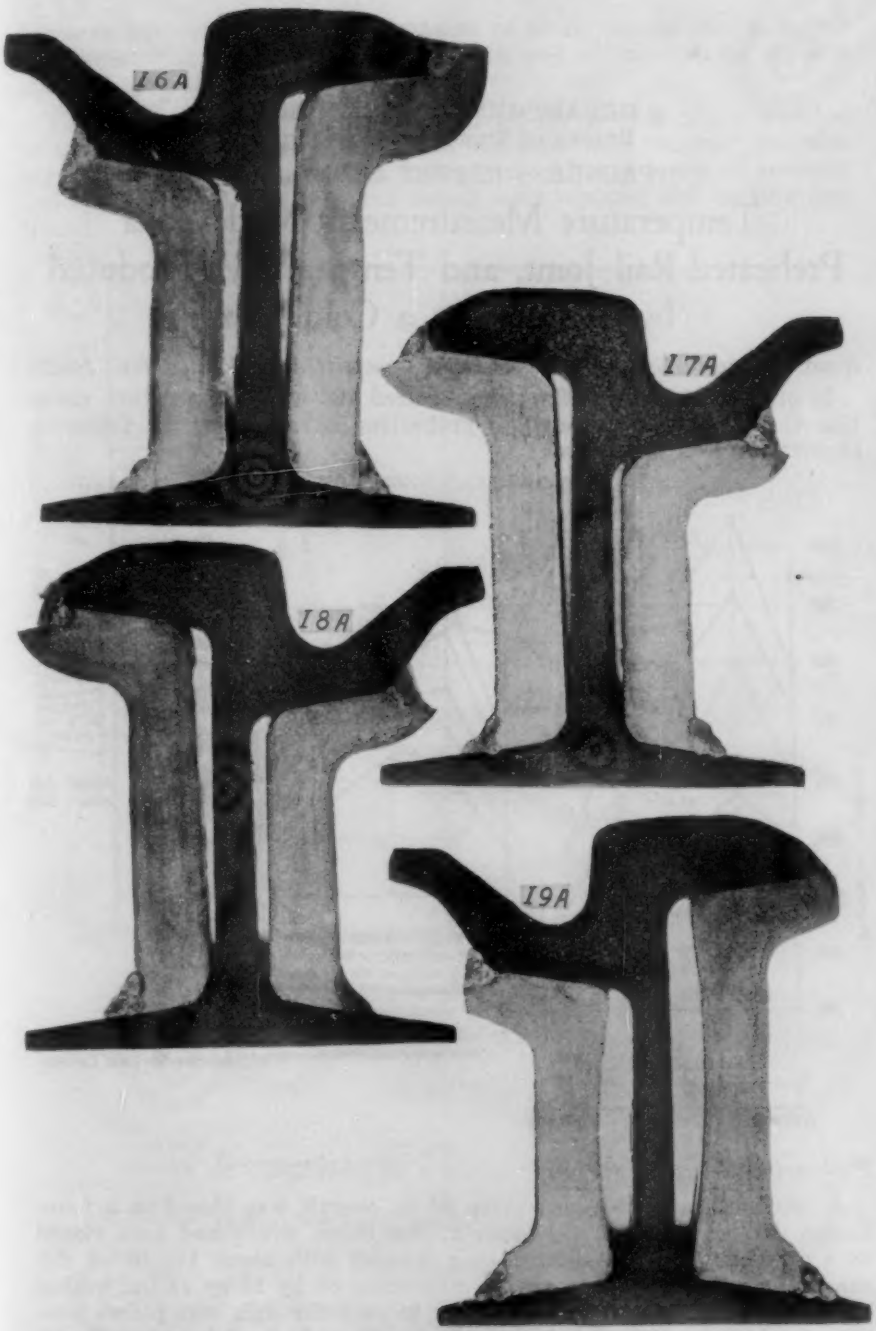


FIG. 24—ETCHED SECTIONS SHOWING CROSS SECTION OF WELD DEPOSIT

DEPARTMENT OF COMMERCE
Bureau of Standards, Washington

PROGRESS REPORT NUMBER 19

Temperature Measurements Made on a Preheated Rail Joint, and Temperatures Produced by Welding on a Cold Joint

Report made to Executive Committee, Committee on Welded Rail Joints

In order to determine the time required and what temperature variation that might be expected in preheating a rail joint, the following experiment was performed.

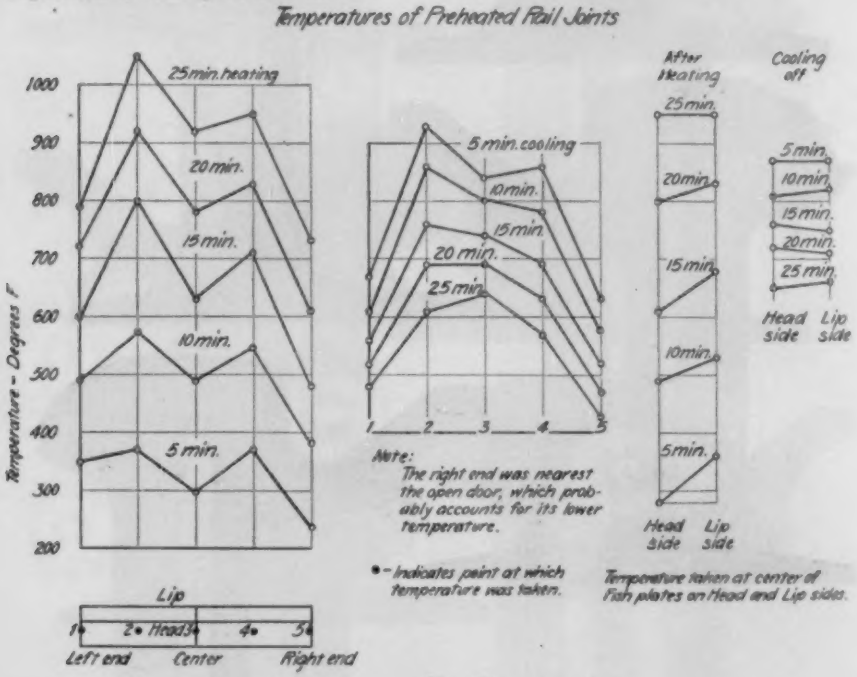


FIG. 25

Preheating Temperature

A specimen rail joint, measuring 53 in. overall, was placed on a foundation that consisted of one layer of fire brick, which had been placed on a concrete floor, the bricks being covered with about 1½ in. of dry sand. An unlined sheet iron oven measuring 36 by 18 by 14 in., having openings in the ends to allow the rail to pass through, was placed over the joint to be heated. The heating flames were obtained from two Hauck

kerosene burners, using an air pressure of 60 lb. per sq. in. A burner was directed through the opening at each end of the oven on opposite sides of the rail joint.

The flames were directed on the rail joint for periods of five minutes, at the conclusion of which the flames and oven were removed and temperature measured by a contact pyrometer. After a series of readings had been obtained, the oven and flames were replaced and heating continued.

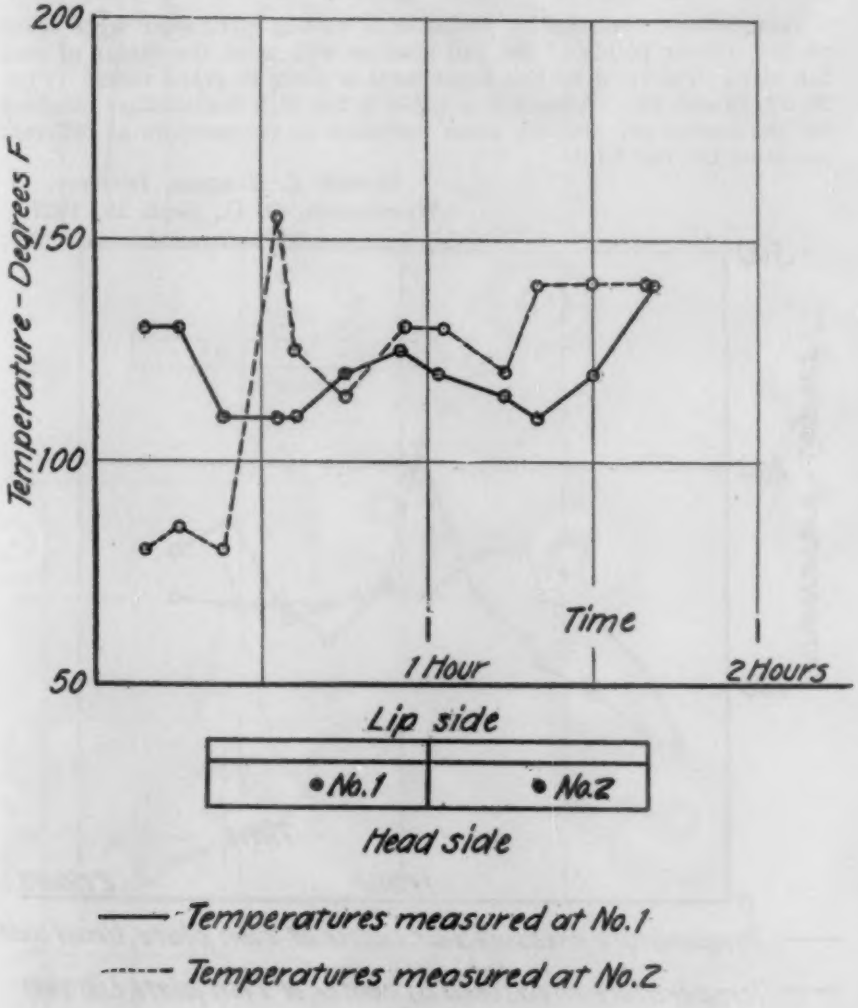


FIG. 26

Temperatures Measured on Head of Rail Joint No. 216F (Metal Electrode)

Temperature readings were taken on the head; at the ends, quarter points, and center; also at the centers of each fish plate. Temperature measurements were also made as the joint cooled; Fig. 25 gives the results of these measurements.

Welding Temperature

Temperature measurements were taken on two rail joints while being welded; one joint was welded by the carbon arc method while the other was welded by the metal electrode method.

Temperature readings by means of a contact pyrometer were taken on the quarter points of the rail head as well as at the center of each fish plate. The result of this experiment is given in graph form. (Figs. 26, 27, 28 and 29.) Attention is called to the high temperature observed for the carbon arc and the great variation in temperature at different places on the rail joint.

GEORGE K. BURGESS, *Director*,
Washington, D. C., Sept. 19, 1927.

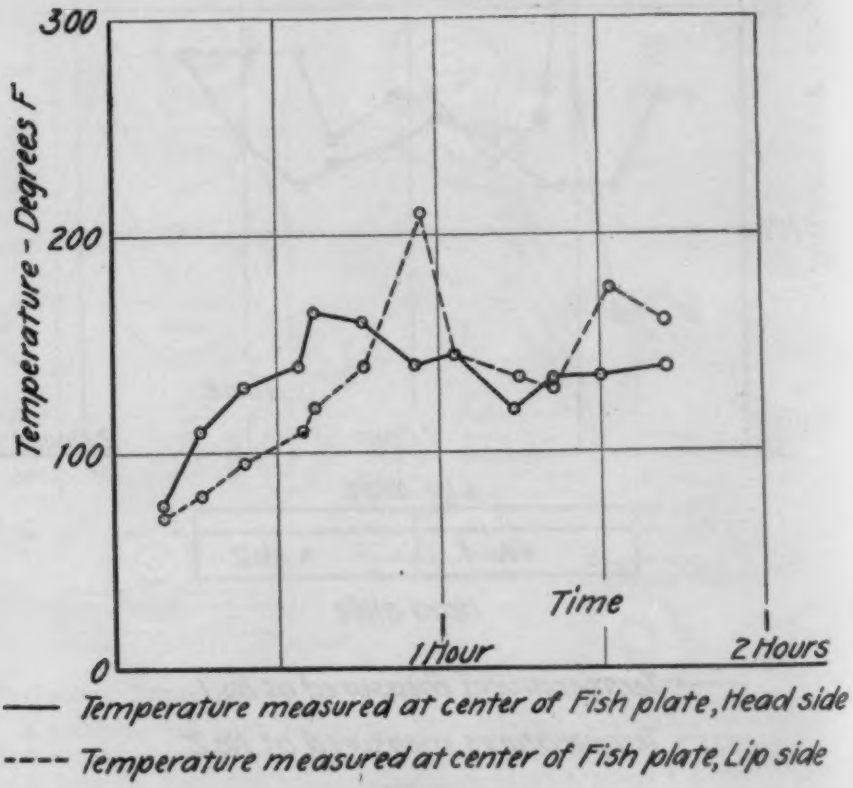


FIG. 27

Temperatures Measured on Fish Plates of Rail Joint No. 216F (Metal Electrode)

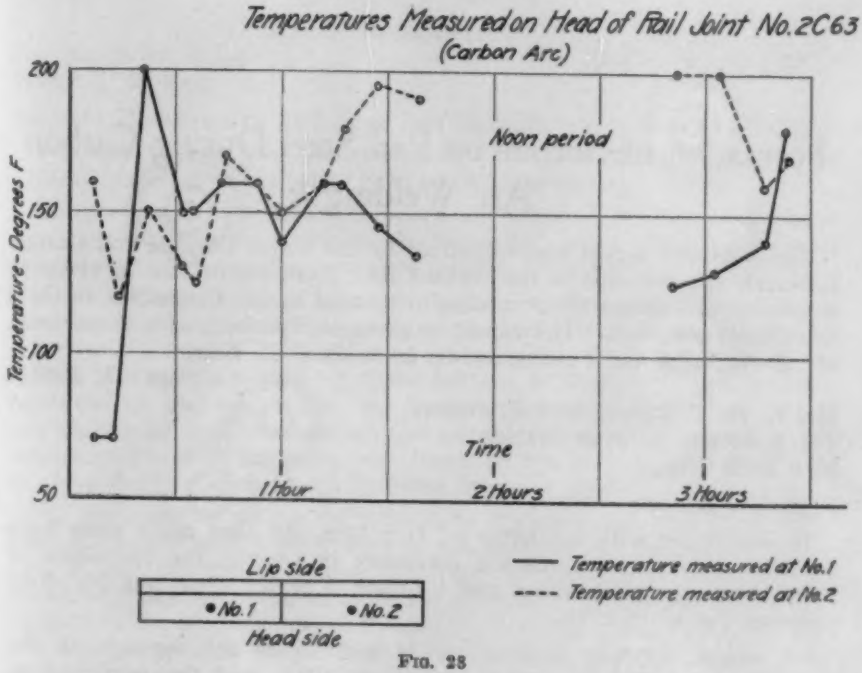

Temperatures Measured on Head of Rail Joint No. 2C63
(Carbon Arc)
200
150
100
50
Temperature - Degrees F
Noon period
Time
1 Hour
2 Hours
3 Hours
Lip side
No. 1
No. 2
Head side
Temperature measured at No. 1
Temperature measured at No. 2

FIG. 28

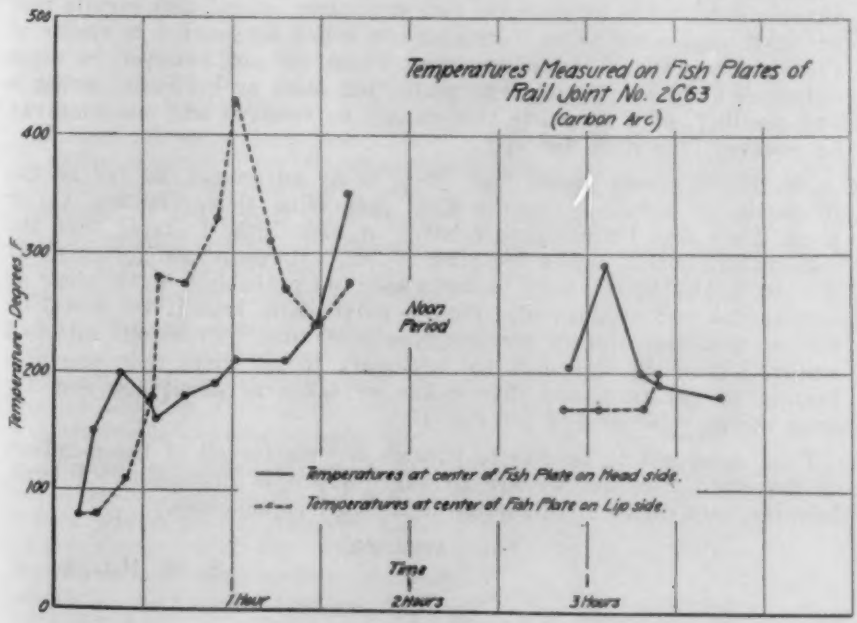

500
400
300
200
100
0
Temperature - Degrees F
Temperatures Measured on Fish Plates of
Rail Joint No. 2C63
(Carbon Arc)
Noon
Period
Temperatures at center of Fish Plate on Head side.
Temperatures at center of Fish Plate on Lip side.
Time
1 Hour
2 Hours
3 Hours

FIG. 29

Formation of Sorbite on Rail Steel During Carbon Arc Welding

The following report was submitted by the Union Carbide and Carbon Research Laboratories to the Welded Rail Joint Committee in order to determine preheating temperatures to be used by the Committee in their investigational work. The report is given in the form of a letter from Mr. S. W. Miller and a memorandum from Mr. J. M. Keir.

Sept. 15, 1927

Mr. E. M. T. Ryder, Way Engineer,
Third Avenue Railway System,
New York City.

Dear Mr. Ryder:

In connection with my letter of July 19th, we have made some tests on the preheating temperature necessary to prevent the formation of sorbite during rail welding, and I attach a report from our Mr. Keir covering the matter.

Of course, whether a structure is sorbitic or not depends on the magnification. It may appear sorbitic at 100X, and the resolution at 1000X may show the structure to be very fine pearlite. There is no sharply defined line between the two structures, except that sorbite may be fairly considered to be a structure in which no pearlite is visible at the highest power of the microscope. There will not, however, be much difference between the physical properties, such as hardness, strength and ductility, of a structure that cannot be resolved and one than can be resolved only with difficulty.

Mr. Keir's report shows that there is no advantage, as far as the formation of sorbite is concerned, in preheating above 600 deg. C., or about 1100 deg. Fahr. In my letter of July 19th, I stated that the temperature should not be too high. I omitted one reason for this. If it is too high, the rail head becomes soft and probably will not wear as well as the rest of the rail. This is particularly true if the metal be held at that temperature for any length of time. From the attached report, I conclude that it is not necessary to use more than one preheating temperature, and that it can be taken at about 500 deg. C., or in the neighborhood of 930 deg. F.

I am sorry not to be able to furnish reports for all of the members of the committee, but we are so busy that it is impossible. I have, however, sent copies of this letter to the various members.

Yours very truly,

S. W. MILLER

MEMORANDUM

To: Mr. S. W. Miller September 15, 1927.
From: J. M. Keir

Subject: *Formation of Sorbite on Rail Steel During Carbon Arc Welding.*

We wish to give you the results of our experiments on carbon arc welding of rail steel preheated to various temperatures.

We have made a number of carbon arc welds in which we applied a small low carbon steel button to the flange of a piece of rail steel which was raised to different temperatures ranging from 100 deg. to 700 deg. C.

We have cut out each of these welded buttons and cross-sectioned them and have made a photographic record at 500 to 1000 diameters in order to aid in the determination of sorbite. We have also used a similar section from each of these buttons to determine the Rockwell hardness all the way across the welded region out to a point which was clearly beyond the welding heat effect. We may say here that the maximum Rockwell hardness was found in the base metal over a zone of about 3/16 in. close by the junction lines.

We are showing in figures from 1 to 7 an average field at 500 and 1000 diameters of the zone close by the junction of the weld. We are also giving in the following table the average maximum Rockwell hardness which we obtained in this zone in each of the cases which correspond to the temperature of the rail steel at which the weld was made.

Temp. of Main Mass of Rail Steel	Aver. Max. Rockwell Hardness Scale B
700°C.	100
600°C.	105
500°C.	106
400°C.	108
300°C.	108
200°C.	110
100°C.	110

It seems, from a close examination of the photographs, that there is an entire absence of sorbite when the rail was at 600 deg. C. or above. At 500 deg. C. the pearlite is less distinctly lamellar but can still be resolved. At 400 deg. C. the pearlite is still less distinct and small areas of sorbite are visible. At 300 deg. C. the pearlite is indistinct and several areas of sorbite are noticeable. This condition increases until at 100 deg. C. most of the area is sorbitic.

These results obtained with the microscope check, in a general way, with the Rockwell hardness figures which we obtained, and there is a slowly increasing hardness with the temperature decreasing from 600 deg. to 100 deg. C., and it would seem that about 300 deg. C. causes a considerable increase in hardness.

Although we cannot say with exactness that any particular preheating temperature prevents the formation of sorbite unless, of course, it be welded within the critical temperature range, we can, however, say that at a temperature of 400 or 500 deg. the base metal will retain considerable softness and sorbite will only be present in relatively small amounts. No purpose is served in preheating above 600 deg. C.

JMK:EK-4 (Sgd.) J. M. Keir.

×1000

B

Same Position as A. All Pearlitic

×500

A

Weld Made at 700° C. Note That the Whole Area Is Pearlitic

Fig. 30

B
Same as A. All Pearlitic
×1000

A
Weld Made at 600° C. All Pearlitic
×500

Fig. 51

A ×500

Weld Made at 500° C. Area Pearlitic

B ×1000

Same Position as A. Note that the Pearlite Is Less Distinctly Lamellar Than at Higher Temperature

Fig. 32

A ×500
Weld Made at 400° C. Areas of Sorbite Visible

B ×1000
Same Position as A. Pearlite Hazy and Indistinct, Areas of Sorbite Distinguishable

Fig. 33

A
Weld Made at 300° C. Lamellar Pearlite Almost Entirely Absent
×500

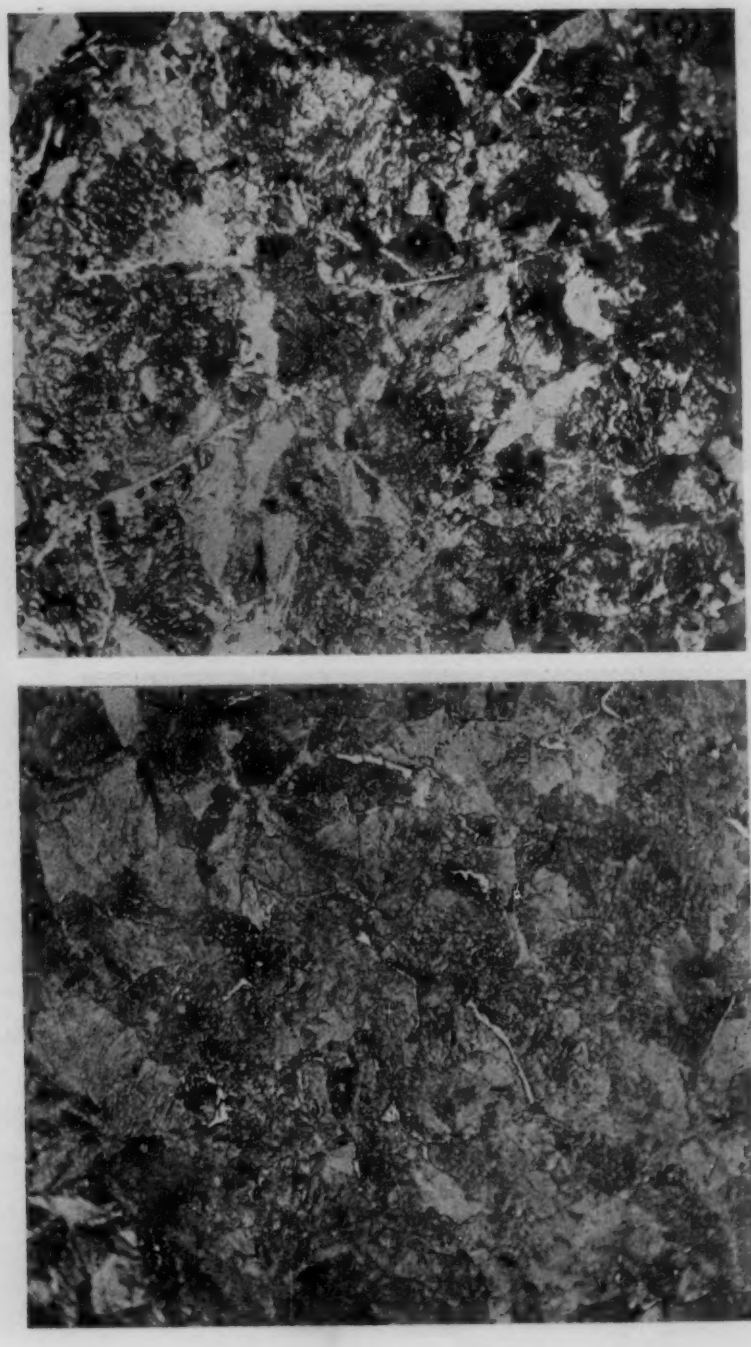
B
Same Position as A. Some Pearlite, But Not Clearly Lamellar. Sorbite Areas Dominant
×1000

Fig. 34

A ×500
Weld Made at 200° C. Dominately Sorbite

B ×1000
Same Position as A, Some Small Areas of Pearlite, But Principally Sorbite

Fig. 35



A ×500 B ×1000

Weld Made at 100° C. Largely Sorbite. Same as A. No Lamellar Pearlite Visible. Mostly Sorbite

Fig. 36

Use of Strain Gage In Determining Stresses and Distortions Caused by Welding

In attempting to use the strain gage to investigate the stresses caused by welding the rail joints and the stresses induced in the joints loaded as a beam, Prof. L. H. Crook, Catholic University, Washington, D. C., and Prof. T. R. Lawson, Rensselaer Polytechnic Institute, Troy, N. Y., very kindly offered to donate this portion of the work.

The results so far obtained show great changes in the length of the gage lines after the welding operation. Some believe that these are caused by high stresses induced by welding; others believe that the heating has caused the changes, which indicate permanent deformations. Although a great deal of time and effort has been expended on this work definite conclusions can not as yet be drawn. The committee feels that the importance of this work justifies continuing this investigation as it offers a basis for redesigning welded rail joints to obtain longer life in service.

The committee is greatly indebted to Professors Crook and Lawson for their personal efforts on this work. Prof. Lawson's report with five out of 66 graphs are given here, which represent the results of 10,000 strain gage readings. A report by Prof. Crook is also included. This work may be considered a summary of the facts received to date done by both investigators.

Strain Gage Tests

RENSSELAER POLYTECHNIC INSTITUTE, TROY, NEW YORK

Jan. 6, 1928.

Mr. E. M. T. Ryder,
Chairman, Committee on Welded Rail Joints,
Third Avenue Railway System,
New York City.

Dear Sir:

I beg to submit herewith my report on the two rail joint tests which were made up for strain gage tests for your committee.

These joints were made up of two pieces of rail, each 24 in. in length, making the total length of the joint 4 ft. The rail is 7 in. girder, Bethlehem Steel Co. section 122-407A, rolled in accordance with A. E. R. A. specifications Wr-2d, Class B. The joint plates are of rolled section, rolled by the Bethlehem Steel Co. and shown in detail on B. E. Ry. Plan B-7985-2 on the plan. A soft steel insert 1/16 in. thick was placed between the rail ends in Joint 1-A and the joint assembled under compres-

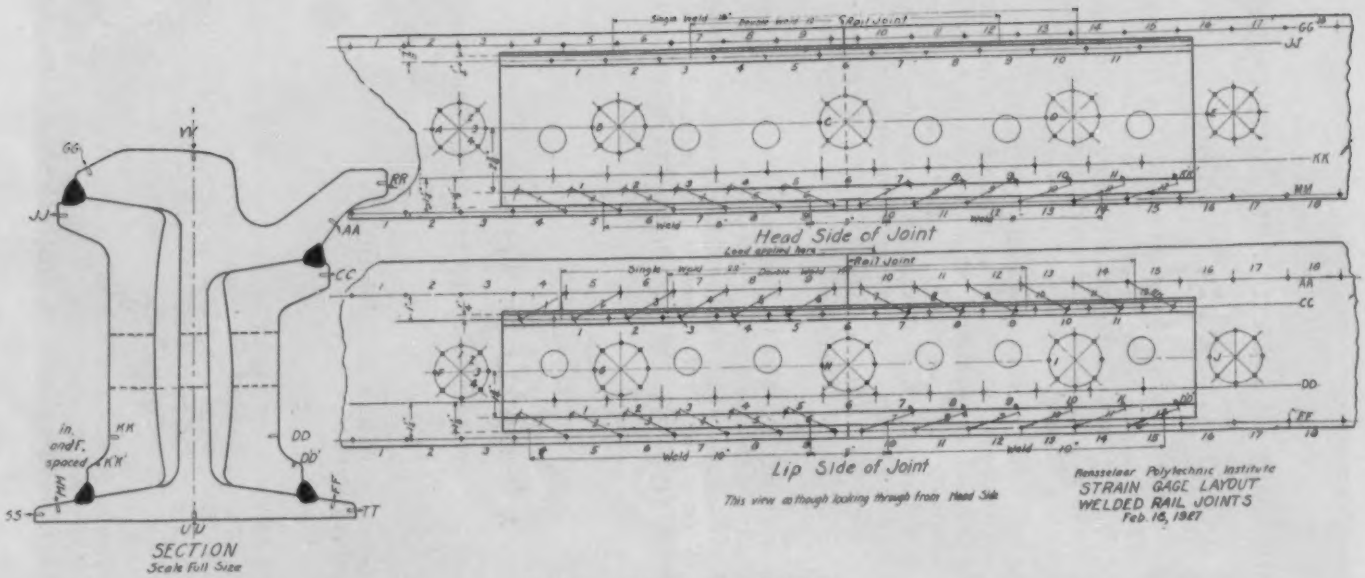
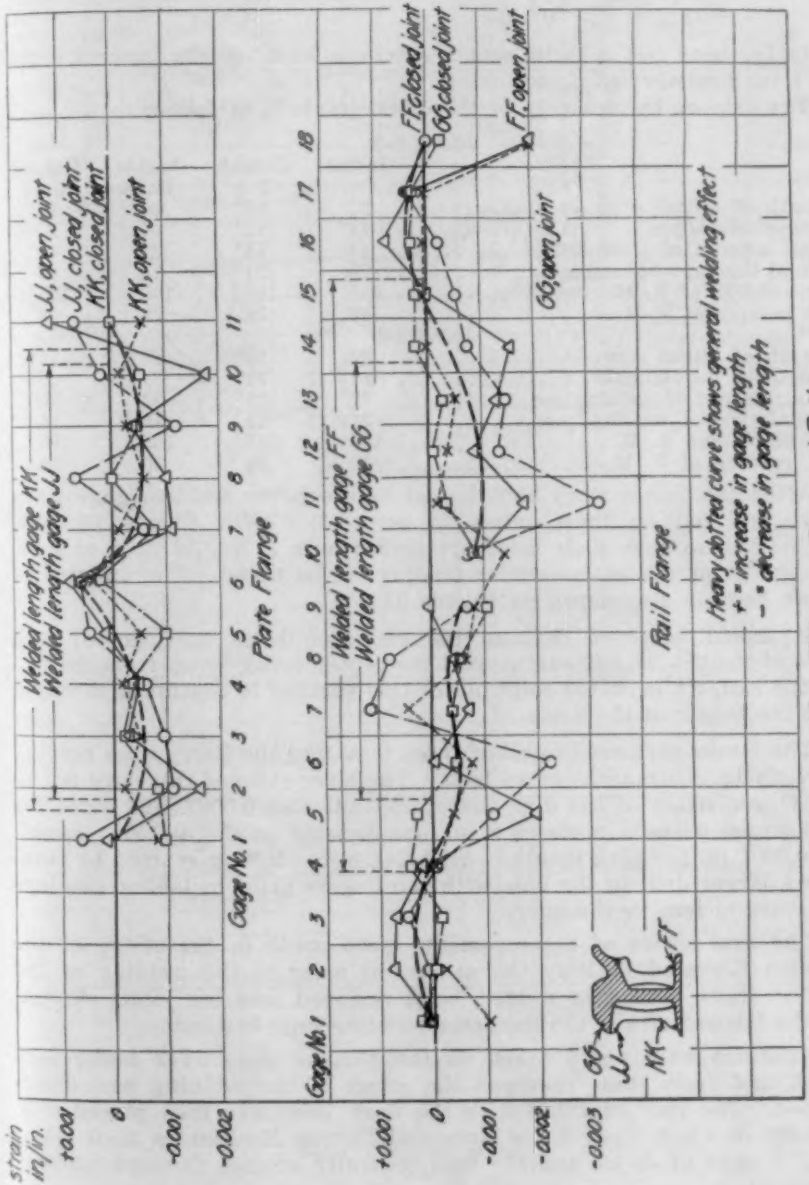


FIG. 37. STRAIN GAGE LAYOUT

Gage lines RR, SS, TT, UU, VV, and gage lines AA, FF, GG, and MM—first hole ½" from end of rail, gage 2"; to be 10 holes on each side of rail joint. Gage lines CC, DD, JJ, and KK, middle of gage No. 6 centered on rail joint, gage 2". Gage lines KK, HH, and D'D', diagonally across welded seam from holes in rail, gage 2". Stars A to J—Middle stars (C and H) centered on rail joint. Circles 2 in. diameter numbered as for A and F. All holes to be accurately spaced and drilled with No. 56 drill, at least ⅛" deep.

sion. In Joint 1-A the insert was omitted so that there was a gap of approximately 1/16 in. between the rail ends. The joints were full bolted during the welding process and later removed. The welding rod used was Una Welding & Bonding Co. 9/32 in. diameter, Grade 200. The joints were welded by the carbon arc hand-feed process and the welding



General Welding Effect on Plate and Rail

FIG. 11

machine used was Una Welding & Bonding Co. dynamotor Type D-4. The temperature of the welding room during the welding was 76 deg. F. The manufacturer's chemical analysis of the joint bars is as follows:

Carbon	0.36
Manganese	0.48
Phosphorus	0.010
Silicon	0.046

In the bend test a ½ in. square specimen bent 180 deg. around a pin of 1 in. diameter satisfactorily.

The data on the make-up of these test joints is as follows:

	Inside Top	Outside Top	Inside Base	Outside Base
Joint 1-A				
Length of initial seam	22″	18″	20″	16″
Length of double weld	14″	12″	..	..
Total amount of welding rod	44″	34″	27″	23″
Actual time of welding, min.	25	21	14	13
Av. reading of A. M.	195	195	190	195
Av. reading of V. M.	38	38	38	38
Joint 1-B				
Length of initial seam	22″	18″	20″	16″
Length of double weld	14″	12″	..	..
Total amount of welding rod	43″	39″	32″	30″
Actual time of welding, min.	21	22	15	14
Av. of reading A. M.	185	185	185	185
Av. reading of V. M.	40	40	40	40

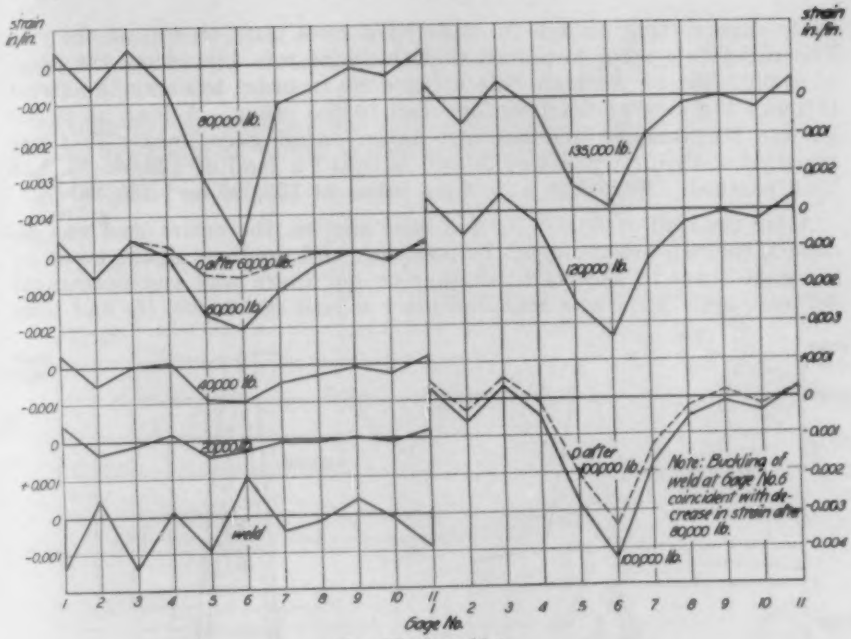
After the joints were bolted, and before being welded, gage lines were laid out on these joints in accordance with Figure 37. On each of these gage lines holes are drilled with a No. 56 drill on 2 in. centers to permit extensometer readings to be taken. The location of these holes is also shown on Figure 37.

It should be noted that on the rail nine holes were drilled each side of the center, the one nearest the center being ½ in. from the end of the rail, while on the joint plates this spacing is continued throughout the length of the plate.

The strain gage used in all of these tests was the Berry gage reading directly to thousandths of an inch. The lever ratio of this gage is 1 to 5. One division of the dial, therefore, indicates 0.0002, and since the measurements were made on 2 in., one division on the dial corresponds to 0.0001 in. per inch length. All holes were slightly reamed by turning a larger drill in the hole with the fingers prior to taking readings in order to remove the burr.

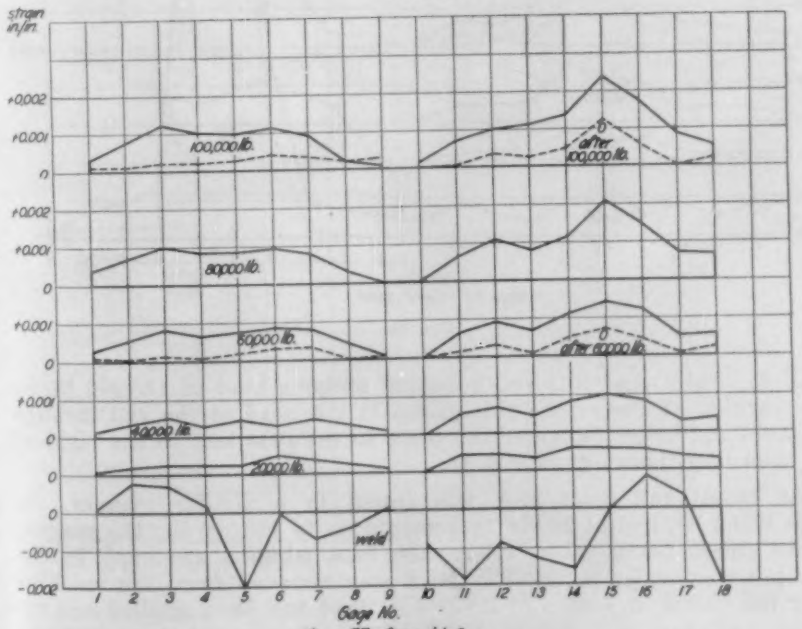
The first series of measurements were made in the shops of the Boston Elevated Railway Co. at Boston prior to the welding of the rails. Rails were then welded, bolts removed, and the joints shipped to the laboratories of the Rensselaer Polytechnic Institute.

Readings were again taken on the various gage lines under zero load, and from these readings the effect of the welding was determined. The rail joint 1-B with the open joint was then placed in a 300,000 lb. Olsen Four Screw Universal Testing Machine on knife edges with a span of 42 in. and the load centrally applied through another



Gage CC - Open Joint

FIG. 39



Gage FF - Open Joint

FIG. 40

knife edge resting on a 2 in. wide hard steel plate on top of the rail. The rail joints were so placed that the joint was 1 in. from the point of application of the load, this being done in order to carry the stress through the side plates from one rail to the other. A load of 20,000 lb. was then applied and readings taken on all gage lines. This was repeated with increments of 20,000 lb. until a load of 120,000 lb. had been reached. Readings were then taken at 135,000 and 180,000 lb.

After the load of 60,000 lb. had been applied, the entire load was removed, the rail taken out of the machine, and readings again taken on the gage lines to ascertain whether or not there was any permanent deformation. This was repeated after a load of 100,000 lb. had been

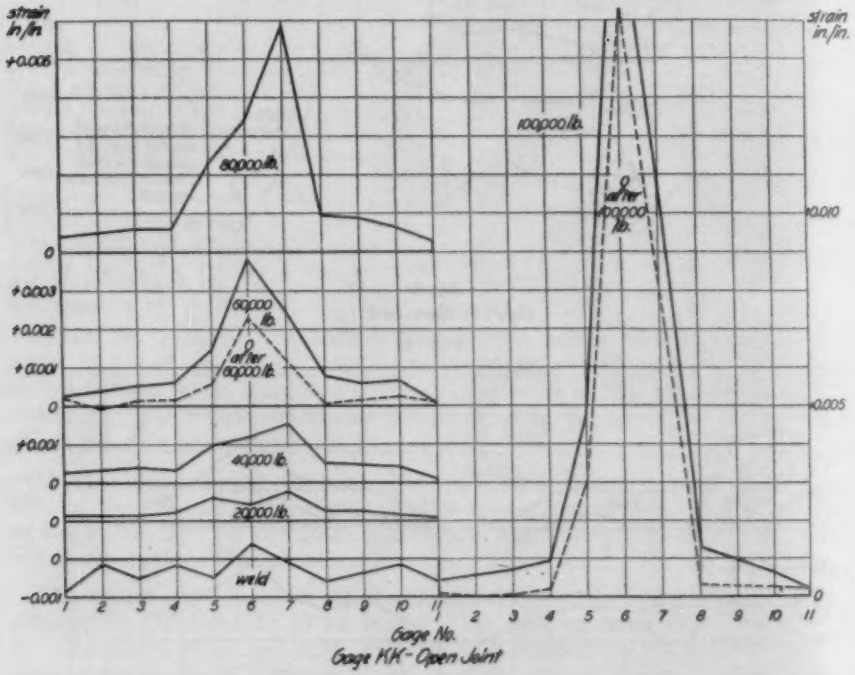


FIG. 41

applied. Failure of this rail occurred under a load of 185,000 lb. by the cracking of one of the side plates at the head of the rail through the weld and lower flange of the plate to the first bolt to the right of the open joint above gage MM 11.

The closed rail joint L-A was tested in a similar manner, the loads being applied at 20,000 increments up to 140,000 lb., the reading of the gages being taken after each load while a specimen in the machine was under load. The joint was removed from the machine after the 60,000 lb. load and 100,000 lb. load had been applied and removed, and readings taken to determine whether or not there was any permanent deformation. This specimen was not tested to failure.

Curves have been plotted for each of the various gage lines which will indicate the distortions that have been produced by the welding and also by the loading.

The curves showing the strains from loading are quite consistent and are about as would be expected, although there were some irregu-

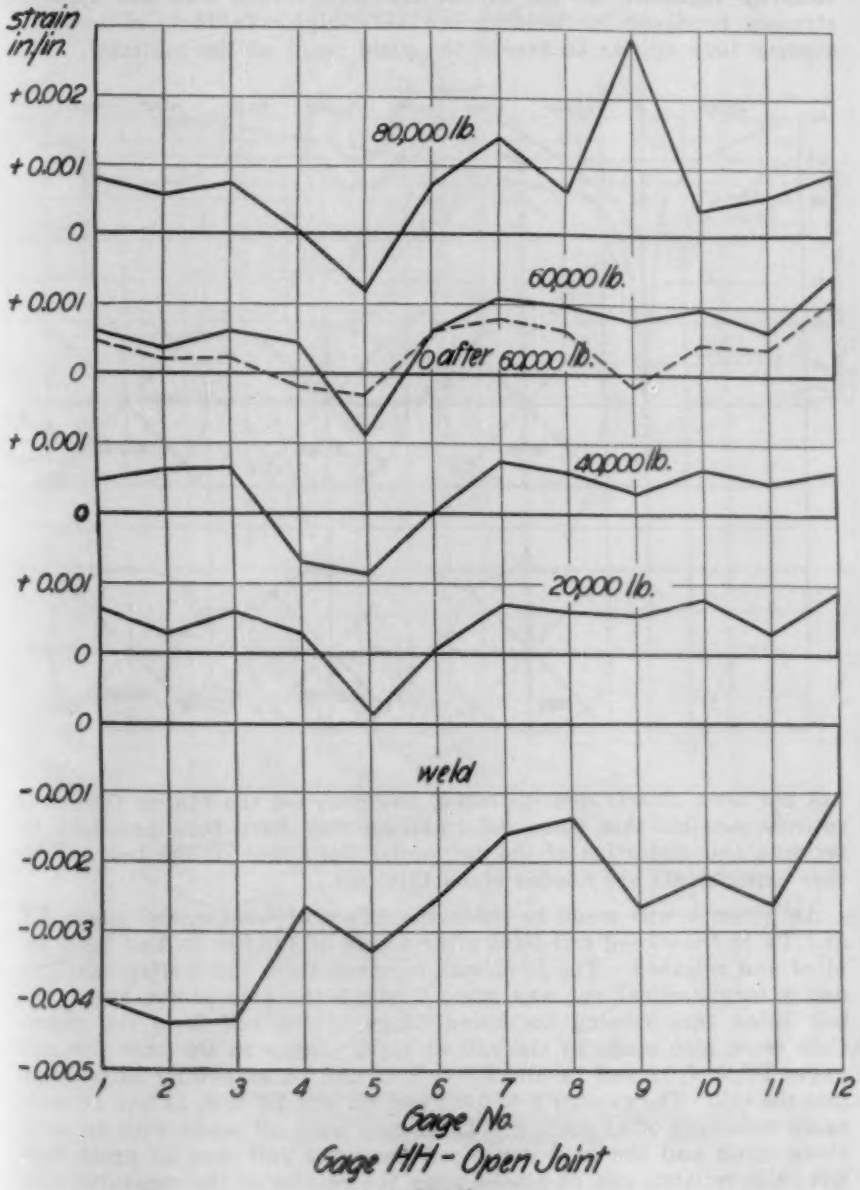


FIG. 42

larities which are difficult to explain, but in general they indicate very clearly that with this particular type of joint the amount of welding was amply sufficient to withstand any static load that might be applied through the application of a car on these rails. The effect of welding is more difficult to explain, and, in fact, can hardly be satisfactorily explained as the curves are very erratic and the apparent stresses produced by welding are very high. In fact, in some instances they appear to exceed the yield point of the material. This

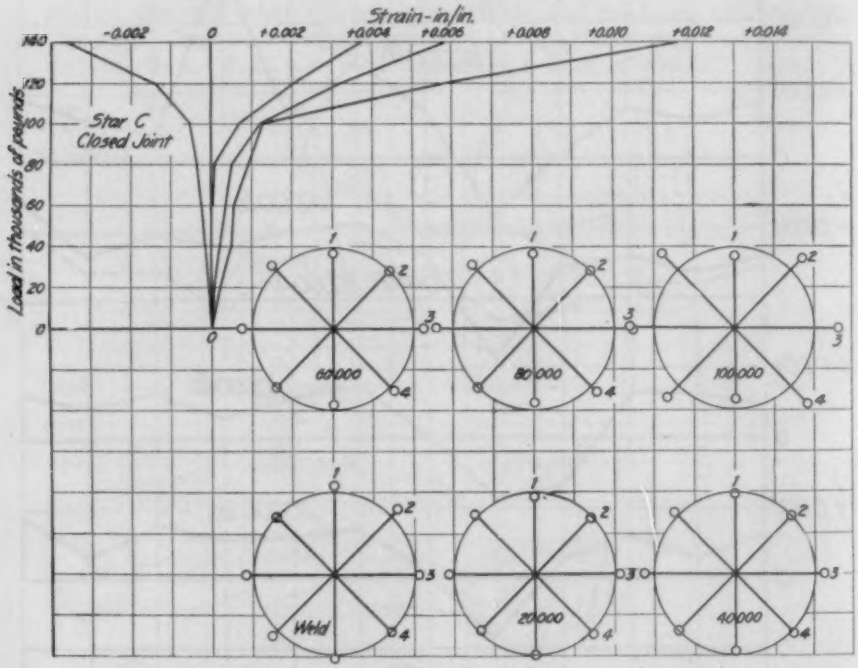


FIG. 43

has not been clearly demonstrated, however, for the reason that it is entirely possible that these deformations may have been produced by bending and distortion of the rail under the action of the heat. Further experiments are needed along this line.

An attempt was made to study the effect of welding on gages FF and TT in the closed rail joint after a load of 140,000 lb. had been applied and released. The joint was removed from the testing machine and a longtitudinal cut was made through the side plates below the bolt holes, thus freeing the lower flange of the rail from the plates. Cuts were also made in the rail at right angles to the axis through gages TT, 5, 7, 12 and 14, and FF 5, 7, 12 and 14, extending halfway up into the rail. The gages FF 6, 8, 11 and 13, and TT 6, 8, 11 and 13 were again measured after cutting. These cuts were all made with an acetylene torch and the heat developed from the rail was so great that but little reliance can be placed upon the results of the measurements

made after the cutting. These results are shown on Figure 44.

Data from the open joint rail for all readings taken also accompanies this report.

This report is submitted as a progress report, and hence no definite conclusions have been drawn from the data as presented, but is submitted for the purpose of information and discussion.

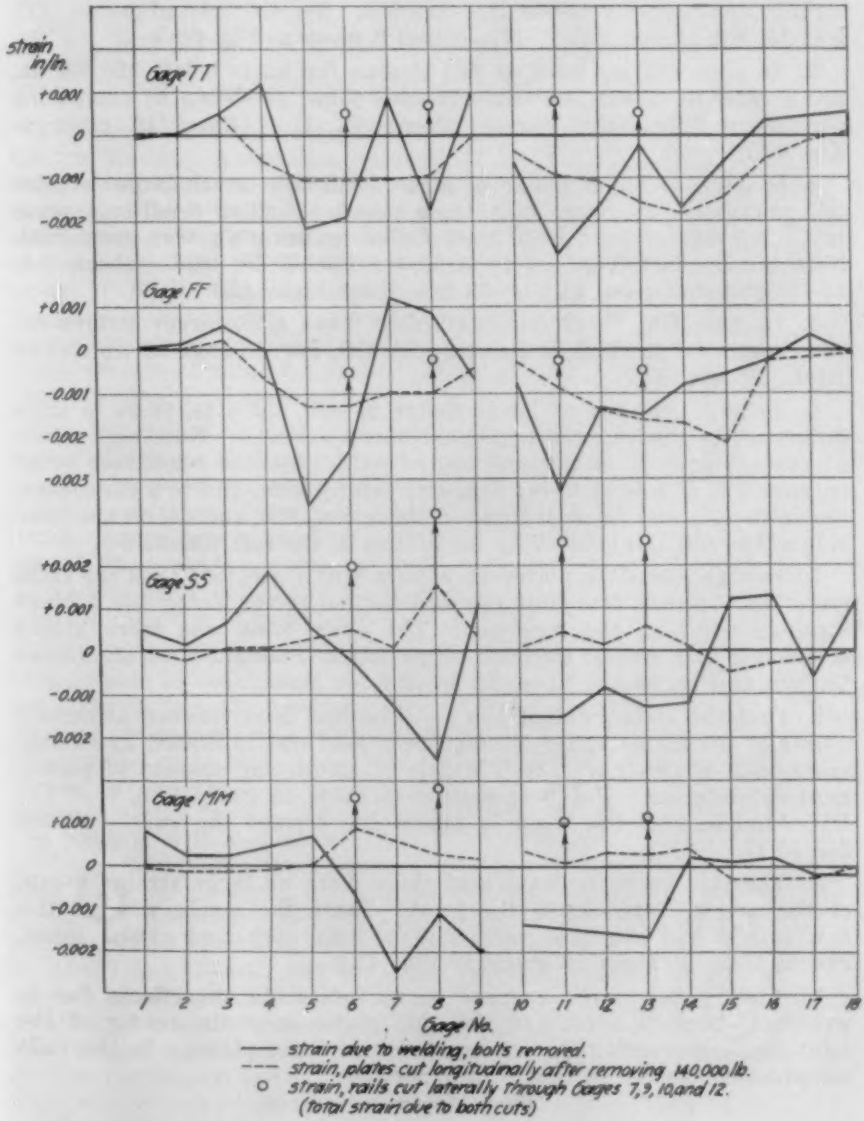


FIG. 44 (CLOSED JOINT)

There are certain observations which have been made as a result of some study of the data and which may be of assistance in further studies. They are as follows:

1. Elastic limit for rail steel of 60,000 lb. per square inch corresponds to deformation of 0.002 in./in. represented by distance of 1 in. on diagram.

2. Diagrams show that some permanent deformation occurs for strains considerably below this amount. See GG, closed joints, CC, FF, JJ, KK Sheets, 2-9, 11-17. (Sheet 3 given as Fig. 39.)

3. In gage GG, on head of rail strains for loads below 120,000 lb., are greater in closed joint than in open joint, as shown by comparing permanent deformation curves, Sheets 10, 11. (Sheet 10 given as Fig. 40.)

4. In gage JJ upper flange of plate, head side, much larger strains in compression in open joint than closed. Similar conditions occur in CC lip side of joint until weld failed by buckling over open joint. Note tension in CC, closed joint, above 100,000 lb. load. Sheets 2-5, 13-15. (Sheet 3 given as Fig. 39 and Sheet 13 as 42.)

5. In gage KK, lower flange of plate, head side, larger strains occur in open joint. This is also true for DD, lower flange on lip side of joint. Sheets 16-17.

6. In gage FF, top of lower flange of rail, lip side, there is little difference between closed and open joint specimens. Note high strain at gages 4 and 15, at extreme end of weld. Similar conditions occur on gage TT, at side of lower flange of rail lip side, and to a certain extent although less in magnitude in the gages MM and SS on the head side of the rail and gage 00 on the bottom of the rail, Sheets 6-9.

7. In both joints the plates were more highly strained than the rails, gage No. 6 across the joint top and bottom flange being the highest strained point in the specimen. The open joint was more highly strained in this respect than the closed joint. Sheets 2-5, 13-17. (Sheet 3 given as Fig. 39 and Sheet 13 as 42.)

8. That the yield point of the material had been reached at certain points of the plates under the 60,000-lb. load was indicated by flaking, magnitude of strain, increase in rate of strain and amount of permanent deformation. This was more noticeable on gages 5, 6, 7, of CC, DD, JJ, KK, and decreased in magnitude toward the ends. Sheets 2-5, 13-17.

9. The star gages indicate that there were no large strains except at the center stars, across the joint. There the strain was positive horizontally and negative vertically in both open and closed joints. Sheets 18-20. (Sheet 18 given as Fig. 41.)

10. Sheet C gives the average curve indicating the effects due to welding. Tension occurs in the side plates over the center of the joint and compression in the remainder of these plates. In the rails compression occurs in the welded portion.

Respectfully submitted,

T. R. LAWSON (Signed).

Aug. 28, 1928.

A Preliminary Report on Stresses in Seam-Welded Railway Rails

By L. H. CROOK† AND J. A. DUGAN†

At the request of the Committee on Welded Rail Joints of the American Electric Railway Association, meeting at Lehigh University on Feb. 3, 1927, two specimen rail joints were prepared and tested for stresses and strains produced by the welding operation only. The plan of test as carried out was substantially the same as that suggested by the Bureau of Standards. The test joints were made and welded under the direction of Mr. W. W. Wysor, chief engineer of the United Railways and Electric Company of Baltimore. The essential part of the test was to drill 2-in. gage distances over selected portions of the specimens and compare the measurements of these before and after welding. A 2-in. Berry Strain Gage was used in these tests.

The rail joints were drilled at the Mechanics Laboratory, Catholic University, taken to Baltimore by automobile, and after a complete set of readings were welded on the street under the same conditions as the rails in practice. They were returned to the Catholic University by auto to ensure care in handling. After the rail joints had returned to the normal temperature the gage readings were again taken, the differences before and after welding were determined and then plotted to the same scale for each row of gage holes.

Fig. 45 gives a one-half view of the rail-joint strain gage lay-out, which is applicable to both joints as well as to the right side of each, which was omitted from the drawing. Rail-joint No. 1 was closed tight at the junction of the main rails while in No. 2, a space of 1/16 of 1 in. was left between the main rail ends. The gage-point lines or rows were made parallel to the length of the joint and are designated by corresponding letters in all the figures. The section drawing in Fig. 45 gives their relative position with respect to the rail joint section. Some of the gage readings were taken from one row to another row in a plane of the rows, in order to detect the relative displacement of the points across the welded material. These measurements on the lip side of the joint are designated by the letters AA-CC and DD-TT and on the head side by JJ-GG and SS-KK, and the results plotted in Figs. 48 and 49 are lettered accordingly. It was found convenient for both reading and comparative purposes to number the gage holes from the center of the rail joint toward the end of the joints. The gage holes are numbered from 1 to 11 in the flanges, and 1 to 5 along the plates. Gage readings plotted as No. 1 will be understood to mean the difference in the reading of the gage

†Department of Mechanics, Catholic University of America, Washington.

There are certain observations which have been made as a result of some study of the data and which may be of assistance in further studies. They are as follows:

1. Elastic limit for rail steel of 60,000 lb. per square inch corresponds to deformation of 0.002 in./in. represented by distance of 1 in. on diagram.

2. Diagrams show that some permanent deformation occurs for strains considerably below this amount. See GG, closed joints, CC, FF, JJ, KK Sheets, 2-9, 11-17. (Sheet 3 given as Fig. 39.)

3. In gage GG, on head of rail strains for loads below 120,000 lb., are greater in closed joint than in open joint, as shown by comparing permanent deformation curves, Sheets 10, 11. (Sheet 10 given as Fig. 40.)

4. In gage JJ upper flange of plate, head side, much larger strains in compression in open joint than closed. Similar conditions occur in CC lip side of joint until weld failed by buckling over open joint. Note tension in CC, closed joint, above 100,000 lb. load. Sheets 2-5, 13-15. (Sheet 3 given as Fig. 39 and Sheet 13 as 42.)

5. In gage KK, lower flange of plate, head side, larger strains occur in open joint. This is also true for DD, lower flange on lip side of joint. Sheets 16-17.

6. In gage FF, top of lower flange of rail, lip side, there is little difference between closed and open joint specimens. Note high strain at gages 4 and 15, at extreme end of weld. Similar conditions occur on gage TT, at side of lower flange of rail lip side, and to a certain extent although less in magnitude in the gages MM and SS on the head side of the rail and gage 00 on the bottom of the rail, Sheets 6-9.

7. In both joints the plates were more highly strained than the rails, gage No. 6 across the joint top and bottom flange being the highest strained point in the specimen. The open joint was more highly strained in this respect than the closed joint. Sheets 2-5, 13-17. (Sheet 3 given as Fig. 39 and Sheet 13 as 42.)

8. That the yield point of the material had been reached at certain points of the plates under the 60,000-lb. load was indicated by flaking, magnitude of strain, increase in rate of strain and amount of permanent deformation. This was more noticeable on gages 5, 6, 7, of CC, DD, JJ, KK, and decreased in magnitude toward the ends. Sheets 2-5, 13-17.

9. The star gages indicate that there were no large strains except at the center stars, across the joint. There the strain was positive horizontally and negative vertically in both open and closed joints. Sheets 18-20. (Sheet 18 given as Fig. 41.)

10. Sheet C gives the average curve indicating the effects due to welding. Tension occurs in the side plates over the center of the joint and compression in the remainder of these plates. In the rails compression occurs in the welded portion.

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Fig. 45 gives a one-half view of the rail-joint strain gage lay-out, which is applicable to both joints as well as to the right side of each, which was omitted from the drawing. Rail-joint No. 1 was closed tight at the junction of the main rails while in No. 2, a space of 1/16 of 1 in. was left between the main rail ends. The gage-point lines or rows were made parallel to the length of the joint and are designated by corresponding letters in all the figures. The section drawing in Fig. 45 gives their relative position with respect to the rail joint section. Some of the gage readings were taken from one row to another row in a plane of the rows, in order to detect the relative displacement of the points across the welded material. These measurements on the lip side of the joint are designated by the letters AA-CC and DD-TT and on the head side by JJ-GG and SS-KK, and the results plotted in Figs. 48 and 49 are lettered accordingly. It was found convenient for both reading and comparative purposes to number the gage holes from the center of the rail joint toward the end of the joints. The gage holes are numbered from 1 to 11 in the flanges, and 1 to 5 along the plates. Gage readings plotted as No. 1 will be understood to mean the difference in the reading of the gage

†Department of Mechanics, Catholic University of America, Washington.

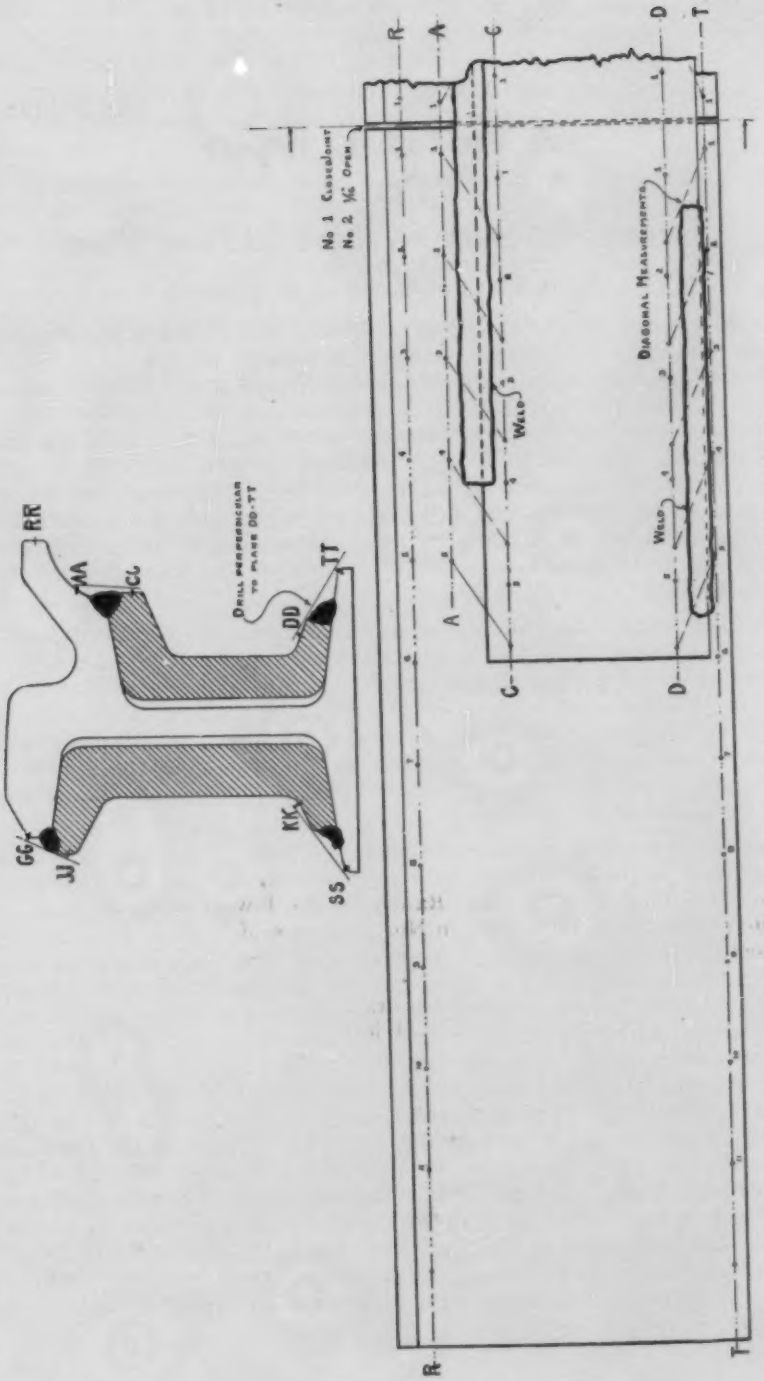

FIG. 45. STRAIN GAGE LAYOUT—SEAM WELDED JOINTS

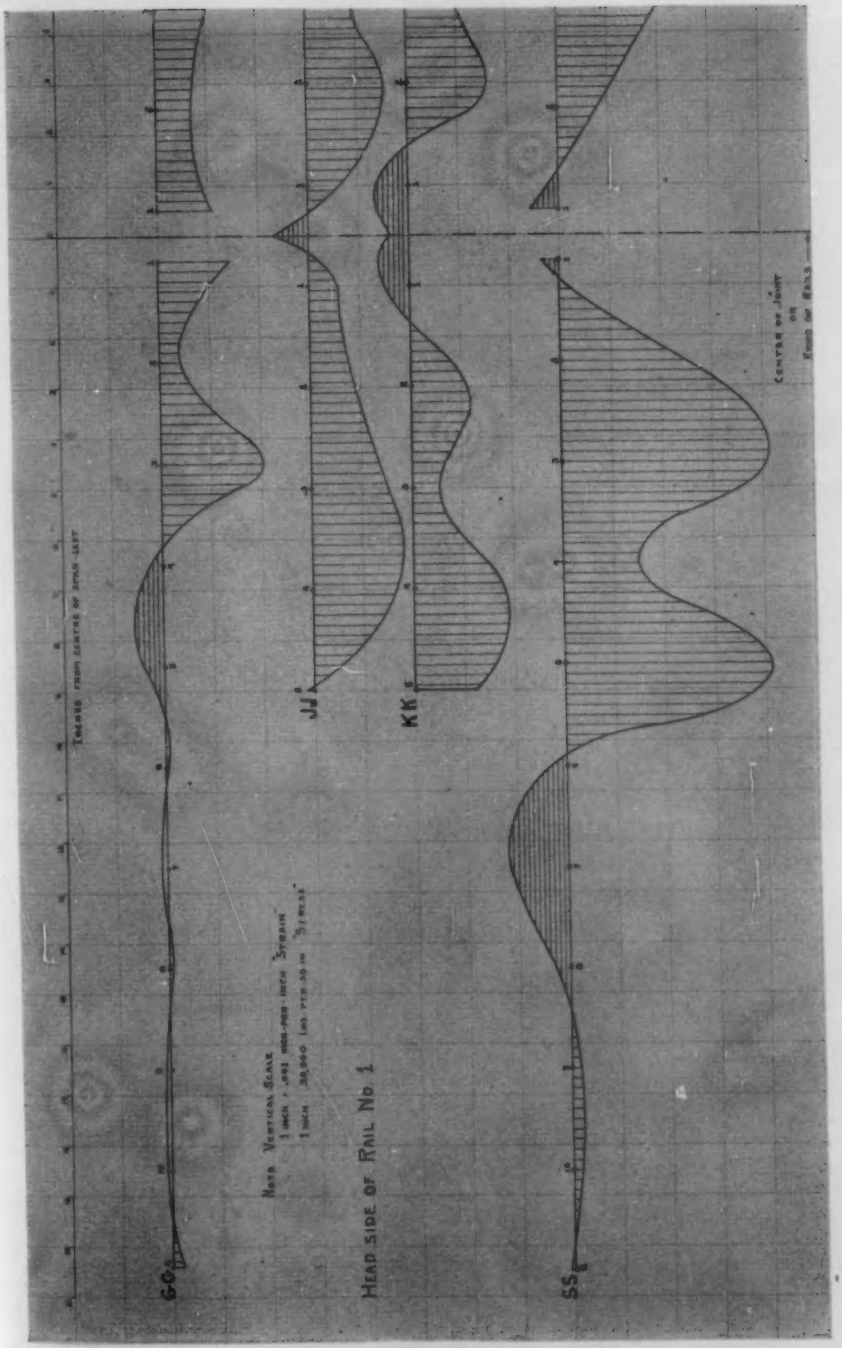

FIG. 46

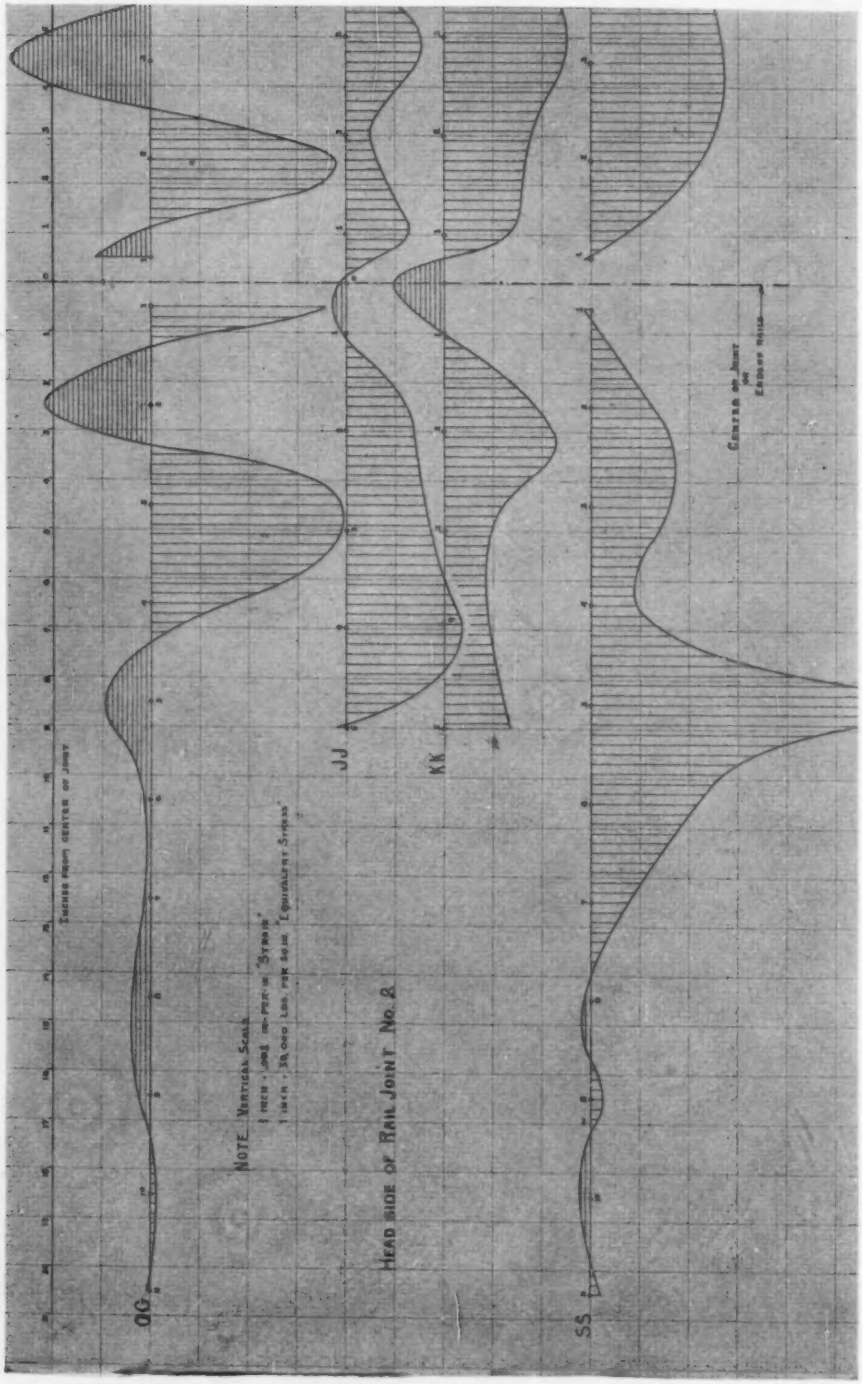
GG
JJ
KK
SS
HEAD SIDE OF RAIL JOINT No. 2.
NOTE. Vertical Scale
Inches from center of joint

FIG. 47

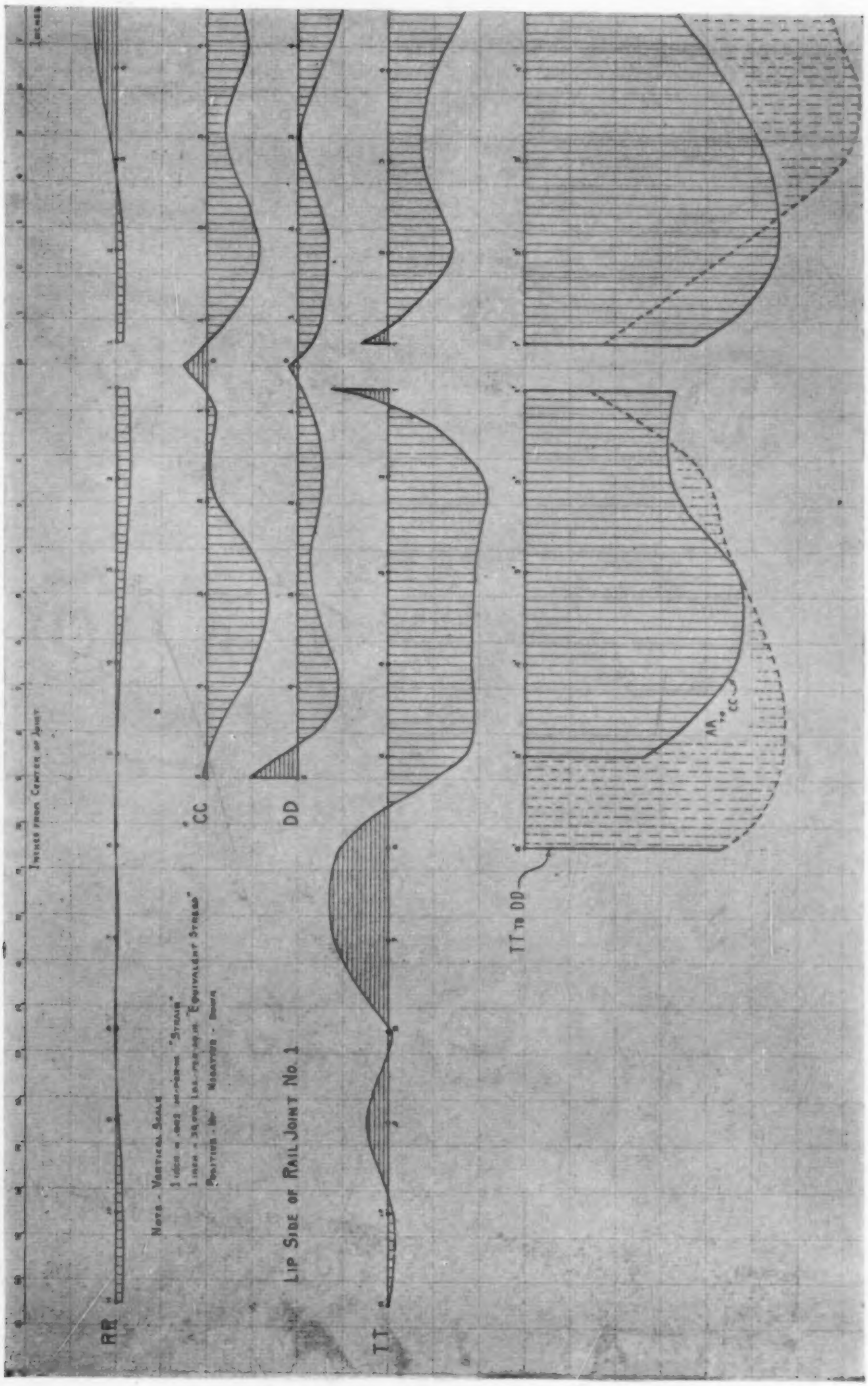

FIG. 48

before and after welding for the 2-in. length between holes No. 1 and No. 2, that plotted as No. 2 for the distance between Nos. 2 and 3, etc.

Figures 46 to 49 are graphical charts of the results of the tests. In all figures the upper chart or graph is for the upper flange, the next below

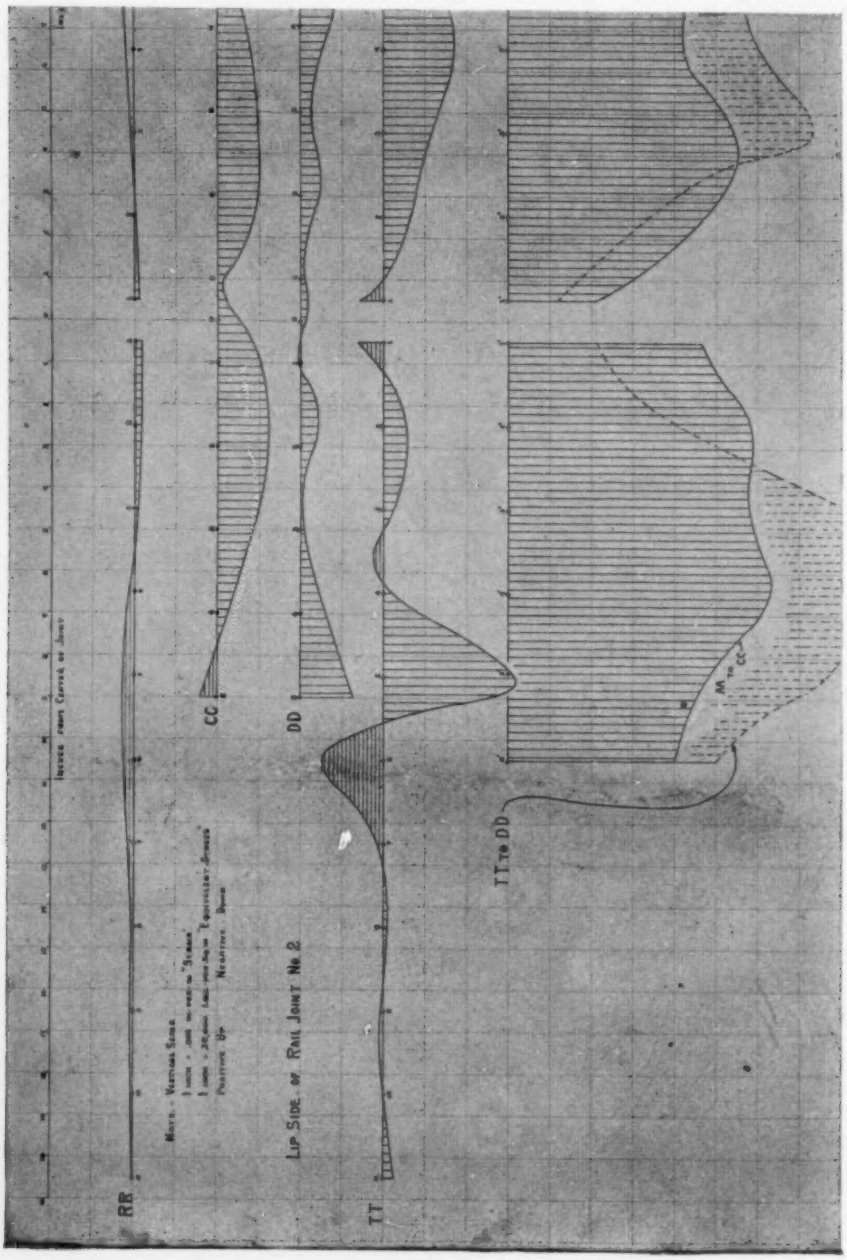

FIG. 49

for the top part of the plate, the next for the lower part of the plate, and the fourth down for the lower flanges. In Figs. 48 and 49 an additional reading has been plotted for the shear along the planes designated by the letters and previously described in Fig. 45. In all cases the small section lines correspond to 30,000 lb. per sq. inch of "Pure Elastic Stress" when elastic stresses only are present, or better to a strain of 1/1000 of one inch per inch of length for all other cases of yields, displacements, or combinations of stresses with yields and displacements.

The graphs given in this report are merely the information that we have received from the strain gage. The analysis of these results is so dependent on our knowledge of the strain gage measurements on flat plates and other simple tests that no attempt will be made at the present time to draw conclusions concerning the strains and stresses. The authors are at present sawing all gage lines, with their adjacent material, from the rail joint in the hope that the additional information obtained for the changes in the strain will enable us to draw more valuable conclusions on both the stresses and the permanent sets or displacements.

August 27, 1928.

Stresses in Flat Steel Plates Due to Welded Bead Along One Edge

By L. H. CROOK†

The following is a report of an experiment performed at the request of the Committee on Welded Rail Joints of the American Electric Railway Association, to obtain information on the magnitude of the tension and compressive stresses in a steel plate adjacent to a welded seam.

A structural steel plate 8 in. by 24 in. by ½ in. thick was used for this test. All measurements were made with a 2 in. Berry Strain Gage and the stresses were deduced from these values by the usual method in which a change of 1/1000 inch-per-inch strain corresponds to a 30,000 pounds-per-sq. in. stress for material having a modulus of 30,000,000. Readings were taken on 2-in. gage points distributed over the flat plate, first, before the welding operation, second, after depositing a small welded bead along the upper edge of the plate, and again after portions of the plate were cut away. The changes in the value of the strain for every 2-in. gage length, with the corresponding change in the value of the stresses forms the subject matter of this report.

Fig. 50 is a mechanical drawing of the standard steel plate used in this test. Two-in. gage points were drilled in seven rows, spaced 1 in. apart, and forming eleven measurements along each row. The dashed lines locate the position of the cuts or the milling operations. The first cut consisted in milling off the welded "BEAD" shown in black. Then ten 1/10 in. cuts were taken in order off the same edge of the main plate

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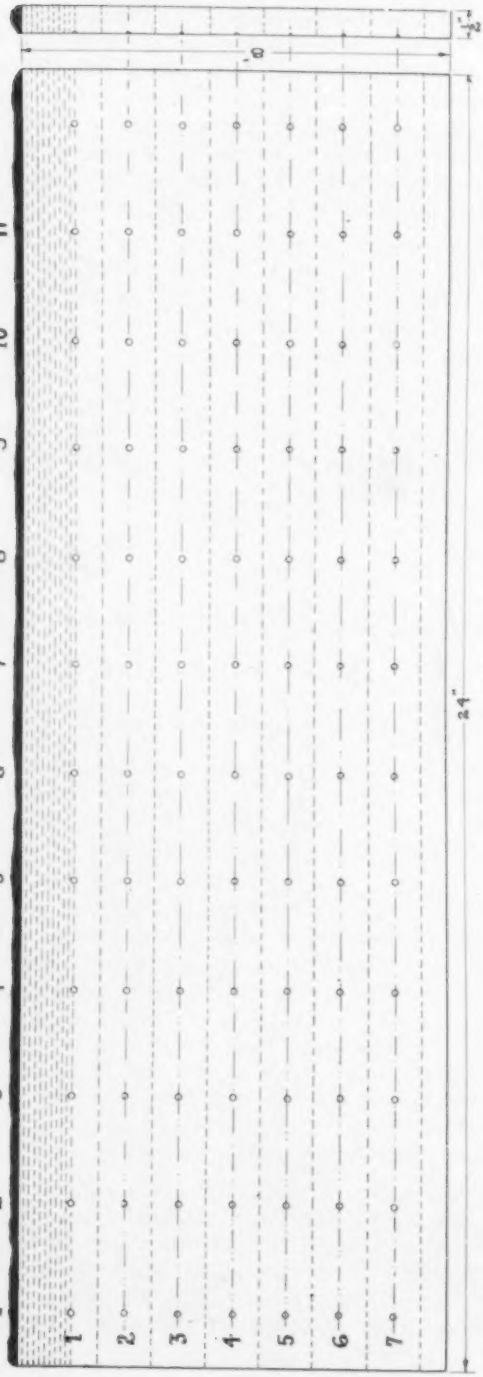

FIG. 50

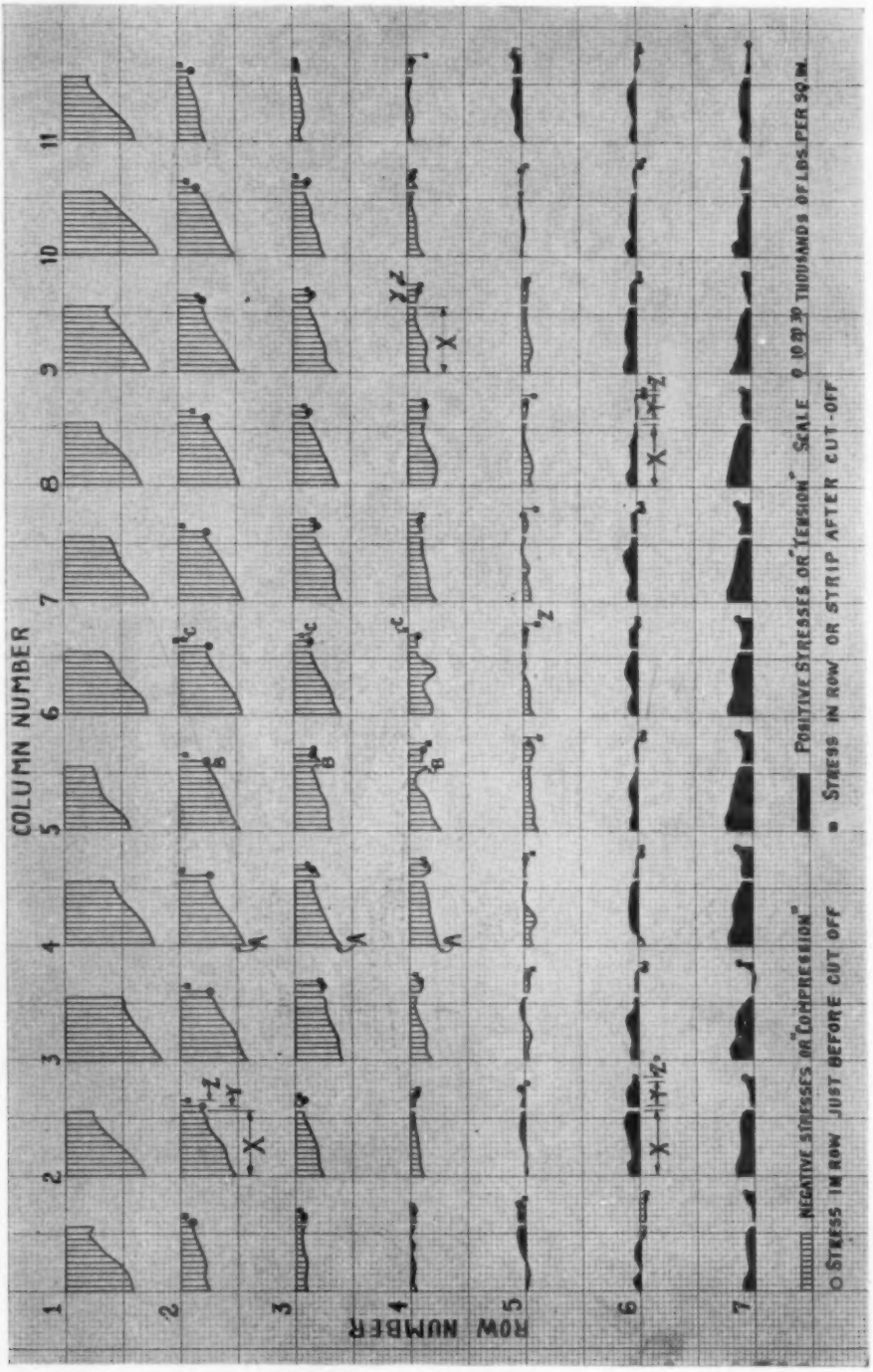
COLUMN NUMBER
1
2
3
4
5
6
7
8
9
10
11
ROW NUMBER
NEGATIVE STRESSES OR "COMPRESSION"
POSITIVE STRESSES OR "TENSION" SCALE 0 10 20 30 THOUSANDS OF LBS. PER SQ. IN.
O STRESS IN ROW JUST BEFORE CUT OFF
STRESS IN ROW OR STRIP AFTER CUT-OFF

FIG. 51

The remaining cuts were made with a saw half way between the rows. All cuts were made in order starting from the upper edge of the plate and ending at ½ in. below the row marked 7. For convenience the gage

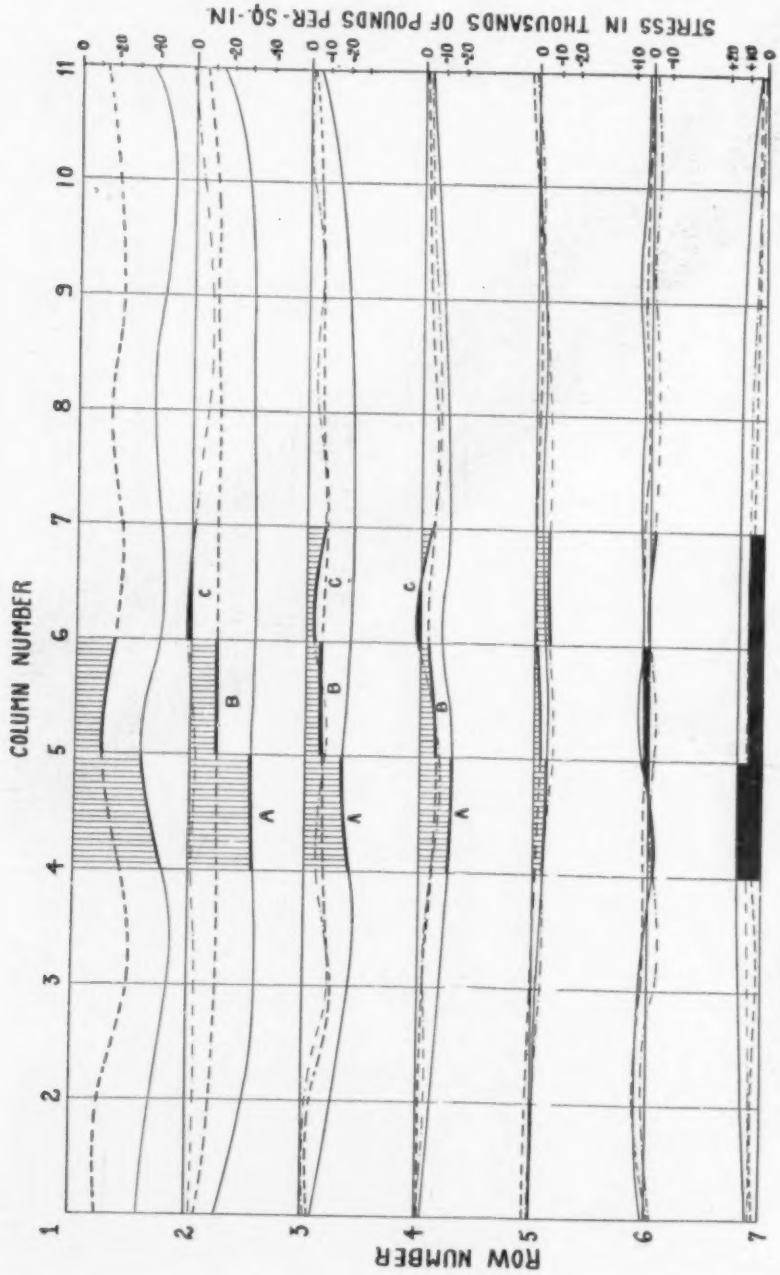
STRESS IN THOUSANDS OF POUNDS PER SQ. IN
COLUMN NUMBER
ROW NUMBER
—— STRESS DUE TO WELD; ----STRESS AFTER CUTTING OFF 1" OF PLATE; ——STRESS IN THE STRIPS

FIG. 52

reading between holes 1 and 2 will be called and also plotted as reading No. 1; that between holes 2 and 3 will be numbered 2, etc.

Fig. 51 shows in graphical form, for each gage point, the complete data obtained from this test. The column numbers and row numbers correspond with those described and shown in Fig. 50. Starting with the graph in row 1 and column 1, the first line of the shaded area represents the stress due to the welding operation only, the second vertical line represents the stress after removing the welded bead, the third after one-tenth of 1 in. has been removed from the main plate; the fourth after two-tenths has been removed from the plate, etc., until the eleventh line represents the stress after 1 in. has been removed from the main plate. A similar interpretation is to be applied to each of the 77 gage point readings shown. The shaded portion is a NEGATIVE (or "COMPRESSIVE STRESS")*, while the solid black is a POSITIVE (elongation of the gage distance, or TENSILE STRESS). The light cross-section lines are spaced to correspond to a scale of 30,000 lbs. per sq. in. At point 6, for example, a negative stress of 40,000 lb. per sq. in. reduces to one of approx. 20,000 after the eleven 1/10 in. cuts have been made.

The portion of the graph marked (X) is for the weld and the ten one-tenth in. cuts, that marked (Y) gives the stress for each point on the main plate after the 1-in. wide strips have been removed, and lastly that portion marked (Z) gives the stress in each individual strip after it was cut from the plate.

Fig. 52 is another graphical chart using values taken from Fig. 51 and replotted and graphed from point to point across the rows. These curves compare three cases of stresses, those due to the welding operation only, those due to the removal of 1 in. from the main plate, and those stresses that remain in the strips after they were cut from the main plate. As before the negative stresses (shrinkage and compressive actions) are shown in shaded section while the positive stresses (tension) are shown in solid black. The scale in pounds per sq. in. is given on the right of drawing for each row. Portions of the curve for each stress compared have been sectioned, respectively, into A, B, and C.

The following conclusions are drawn from the results shown in the figures.

1. Large True Elastic Stresses Exist in the Plate

In Fig. 3, row 2 (2 in. from the welded material), an elastic stress of 30,000 lb. per sq. in. is reduced 50 per cent by cutting away the first 1 in. of the plate and in turn reduced to zero when this row of gage holes is cut away from the plate into a separate strip.

A comparison of the shaded sections in Fig. 52 (typical samples being marked A, A, A), with the corresponding typical samples marked B, B, B, show that this 50 per cent reduction of stress due to the first

*The author does not care to call this a "compressive stress," but rather a negative stress, because it is made up of two kinds of negative conditions that cause a shortening of the gage point distance. One portion of the negative stress is caused by the shrinkage or molecular shift and another portion by the true compressive stress coming from the "field" forces. The comparative values of the two kinds of negative stresses that make up the total measured negative gage reading can be determined from the curve slopes as shown in Fig. 51.

1-in. of main plate functions at all rows in the plate. Furthermore, the curves of Fig. 51 show that this reduction of stress was gradual with each one-tenth of an inch cut from the plate.

2. The welded material plays a very small part in the equilibrium of stresses. The plate adjacent to the welded material plays a very important part at a distance of 15 to 20 times the thickness of the welded material, gradually fading off to zero at considerably greater distance from the weld.

This is illustrated in Fig. 51. The slopes of the curves are uniform and show the effect of removing the welded material is no more than that of removing each one-tenth of 1 in. from the main plate. The welded material perhaps does not play even 5 per cent in the stress troubles.

3. Independent strain-gage readings taken close to a welded seam cannot be interpreted in terms of true stress but when considered in conjunction with other strain gage readings, at known distances from the weld, the true elastic stresses may then be interpolated.

The strain gage measures both the permanent set and the elastic strain by the same unit (LENGTH) and gives the algebraic result. The strain gage is ideal in a pure elastic stress field but must be interpreted with care in a combination field. Another method of a more practical nature is to remove the section measured from the field of stress and interpolate the result for both permanent set (shrinkage) and true stress from the change in the rest of the field. The problem of the determination of these true elastic stresses is much the same as that of the electric stresses in an electric field in both of which the "field" stresses play a very important part.

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Elkonite is the only welding material which can be economically used on the new Welded Spoke Lincoln and Ford Wire Wheels. Elkonite welds are strong. Hard copper and various alloys fail at once but Elkonite dies give 10,000 perfect welds . . . an outstanding success in the history of welding!

Let our engineers show you how Elkonite can be used effectively in your field also—no obligation.

ELKON, Inc.

Division of P. R. Mallory & Co., Inc. 350 Madison Ave., N. Y. C.

Instruction Manuals

The Educational Committee of the American Welding Society has issued instruction manuals for Arc, Gas, Resistance and Thermit Welding. A few copies of the bound volume of these manuals are still available at $2.50 per copy. Individual courses may be obtained at 50c. per copy. (Resistance course 35c.)

New 1929 Model!

FUZON ARC WELDER

A truly Portable Unit ~

GAS ENGINE DRIVEN

No matter where the job is, this welder can be taken to it! New principles of design are incorporated, eliminating induction coils, reactors and other troublesome adjuncts. Has but one single control, giving an infinite number of current gradations. Extremely easy to operate.

Write for Bulletin.

FUSION WELDING CORPORATION

Welding Equipment and Supply Division of Chicago Steel & Wire Company

Engineers—Manufacturers—Merchants

103rd STREET AND TORRENCE AVENUE, CHICAGO

THERE IS EXCELLENCE

IN WORKMANSHIP

WHERE

SKILL AND GOOD TOOLS MEET.

PUROX

WELDING AND CUTTING TORCHES

REGULATORS, WIRE AND SUPPLIES.

DENVER PUROX COMPANY COLO.

BRANCHES IN ALL PRINCIPAL CITIES.

Acetylene gas cuts anything—.....but

SHAWINIGAN CARBIDE

cuts costs

for Welding, Cutting and Lighting

SHAWINIGAN PRODUCTS CORPORATION

110 WILLIAM STREET, NEW YORK CITY

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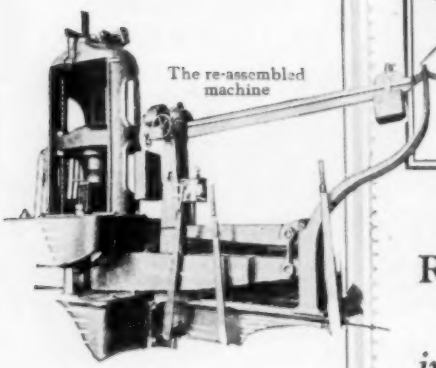

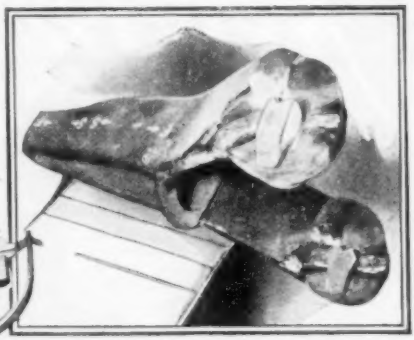

This lever arm Repair-welded with TOBIN BRONZE *in less than two hours*

The top portions of both sides of the lever arm of a testing machine in the University of Wisconsin laboratory were accidentally broken. Welding without dismantling and extensive preheating seemed an impossibility until the University authorities were advised that the fractured parts could be welded quickly and cheaply with Tobin Bronze.

The work was undertaken and the job successfully completed in less than two hours, whereas if the same work had been done with iron, much more time would have been required. That the welded lever is now as strong as ever is indicated by the fact that upon several occasions it has been subjected to a pressure of 220,000 pounds without showing signs of strain, and is giving as reliable service as at any time prior to the fracture.

THE AMERICAN BRASS COMPANY
General Offices: Waterbury, Connecticut
Offices and Agencies in Principal Cities

ANACONDA
WELDING RODS

ANACONDA

For general welding of cast-iron by the oxy-acetylene process, use Tobin Bronze Rods, manufactured solely by The American Brass Company. Be sure the name "TOBIN BRONZE" (Reg. U. S. Pat. Off.) is stamped in the metal—then you may expect durable welds, tougher and stronger than the castings, without the necessity of extensive preheating.

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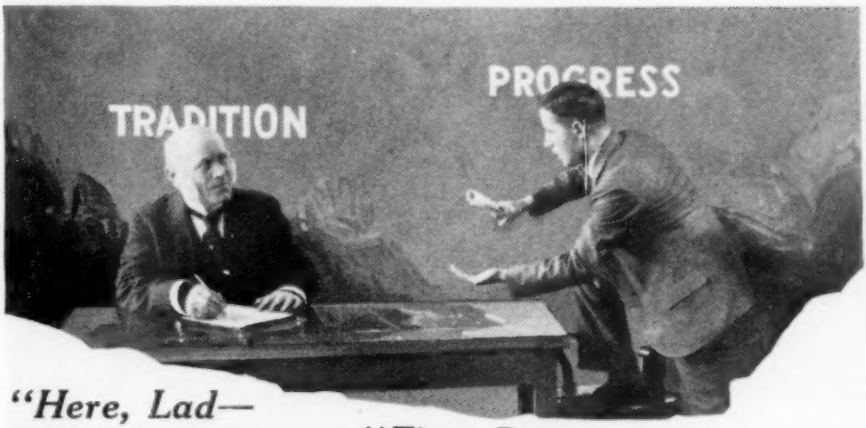
Lad does some campaigning



"Here, Lad—

I've just been taking a straw vote around here to see whether arc welding will better our net income, which is away off this year.

It may be interesting for you to learn that you are the only one that brought up the fact that one make of machine would give us better NET results than any other make."

Only "Stable-Arc" Welders have all these features

Variable Voltage.
Laminated Magnetic Circuit.
Separately-excited Generator Field.
Double Control of Welding Heat.
Steady Arc Throughout Entire Welding Range.
All Steel Construction.
Full Capacity for either Metallic or Carbon Arc Welding.

These features make welding easier. Results — better welds and greater output.

Ask any Operator!

"Fine, Pop—

a straw vote is simply to show how people are thinking.

And did you ever see the majority think any other way than in a circle?

Arc welding from one machine is better for our NET than arc welding from a different make.

Here's an actual case (particulars on request):

A Lincoln 'Stable-Arc' welder produced 1056 feet of welded plate work.

Alongside of it another make of machine under identical conditions of time and work, welded 890 feet of the job.

You don't need an adding machine to tell you that one machine is better for our net than the other.

And you'd better get that Lincoln machine because what we need more than a straw vote right now is a HAY-MAKER."

The Lincoln Electric Co., Dept. No. 22-10, Cleveland, Ohio

W-63

"Stable-Arc" LINCOLN WELDER

Our Advertisers Are Supporting the Society.

NATIONAL CARBIDE

COAST TO COAST

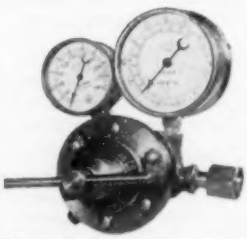
In the RED DRUM

Best for HOUSE LIGHTING · MINERS LAMPS OXY-ACETYLENE WELDING and CUTTING

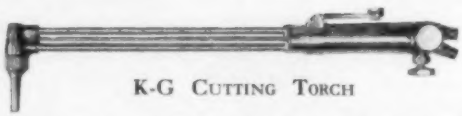
Saves You Money

National Carbide Sales Corporation . 342 Madison Avenue . New York, N. Y.

K-G ACETYLENE REGULATOR



K-G OXYGEN REGULATOR



K-G CUTTING TORCH

Gas Welding and Cutting Equipment and Supplies

K-G WELDING & CUTTING CO., Inc.

515 West 29th St. N. Y. City

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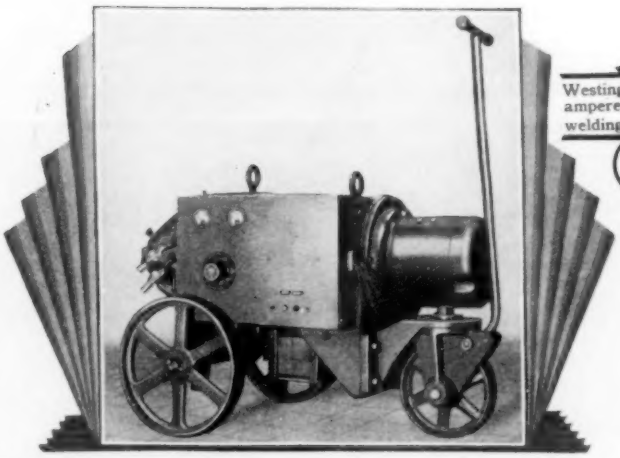

Westinghouse 200-ampere a-c., d-c. welding set

Advantages *of this* Welding Set–

1 *Easy to Operate*—Faster work and better welds result from the use of this new Westinghouse set because the generator produces a steady penetrating arc which is easy to strike and maintain. Push-button starter.

2 *Economical*—The LINESTART motor and LINESTARTER make up an economical driving unit. Low maintenance cost as parts are protected by being enclosed.

3 *Adaptable*—A general purpose welding set, rated at 200 amperes but having a range up to 300 amperes. Suitable for shop or field structural work.

4 *Self-Contained*—The machine is a compact unit—the motor, generator, and control equipment being contained in a single rigid frame. All moving and current-carrying parts are enclosed.

In addition to this set, Westinghouse has introduced a 300 and a 400-ampere portable welding machine for use where heavier currents are needed. Write for information.

Arc Welding Data

Separate series of bulletins are available for

Executives
Engineers
Production Men
Welders

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of the United States and Foreign Countries

Westinghouse

T-30104

"Who is *that* man?"

"He looks sort of familiar. Does he belong here?" asked the superintendent.

"He isn't on our payroll," replied the master mechanic, "but he sure gives us a lot of help with our welding. He's the Linde Service Supervisor. When we run into a tough job—like that new high pressure steam line, he's the man that shows us how to do it. Knows his business and ours where welding is concerned."

If your job involves more than ordinary welding technique, the Linde Service Supervisor is at your call. He is part of Linde Process Service which is free to Linde customers.

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide UCC *and Carbon Corporation*
General Offices: Carbide and Carbon Building
30 East 42d Street, New York
54 PLANTS - 98 WAREHOUSES

LINDE OXYGEN

"A product of Union Carbide"

Prest-O-Lite Dissolved Acetylene is a product of Union Carbide and Carbon Corporation. There is no better guarantee.

Beginning 23 years ago, facilities for the distribution of Prest-O-Lite have always kept pace with the ever increasing demand, until today Prest-O-Lite is readily available everywhere through

33 PRODUCING PLANTS—161 WAREHOUSES

Prest-O-Lite
DISSOLVED ACETYLENE

THE PREST-O-LITE COMPANY, INC.
Unit of Union Carbide UCC *and Carbon Corporation*
General Offices: Carbide and Carbon Building
30 East 42d St., New York

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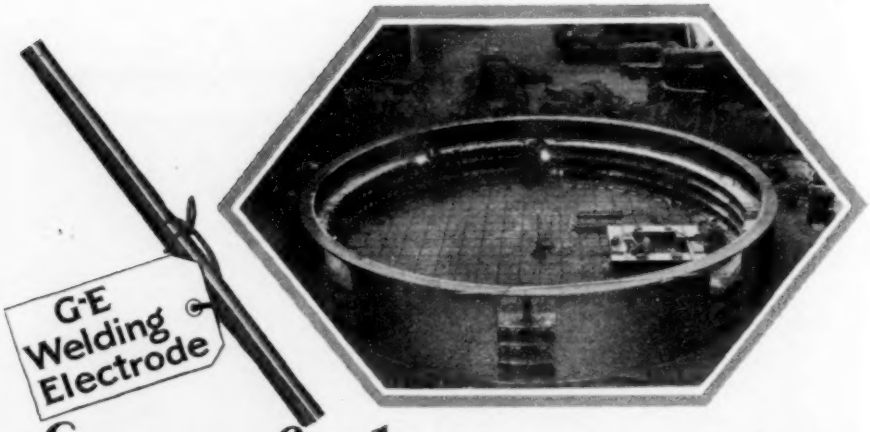


for unfailing service

This giant generator frame is a part of the Conowingo water-power development. It will be subjected to severe, continuous, and long operation. Arc welding has prepared it for unfailing service—arc welding and G-E welding electrode.

More and more, fabricators of iron and steel are turning to arc welding. This new, improved method of construction necessitates electrodes which assure sound, tough unions. You need not worry about welds of uncertain quality when any of these tried and tested G-E welding electrodes are employed:

Type "F" is used for the general welding of steel.
Type "B" is best for automatic welding.
Type "A" is recommended for cast iron.

Special distributors for G-E welding electrodes, located throughout the country, are equipped to give you prompt service. Get in touch with the G-E Welding Electrode Distributor near you or write to the Merchandise Department, General Electric Company, Bridgeport, Connecticut.

550-208 D

GENERAL ELECTRIC

MERCHANDISE DEPARTMENT BRIDGEPORT CONNECTICUT

Our Advertisers Are Supporting the Society.

Atomic Hydrogen Arc Welding

This new welding process—the latest of General Electric's long list of contributions to the welding industry—is attracting widespread interest.

The atomic hydrogen arc welder welds metals and alloys hitherto considered unweldable.

It welds thin metals—as thin as .005 inch.

It produces smooth, ductile welds.

It is simply constructed, mechanically and electrically.

It is safe and easy to operate.

It is available for hand operation from 60- or 50-cycle, single-phase circuits.

Here are shown installations at the Crosby Co. of Buffalo and the Taylor Instrument Co. of Rochester.

Address all inquiries to your nearest G-E office.

THE MORE YOU ARC WELD THE MORE YOU SAVE

530-44D

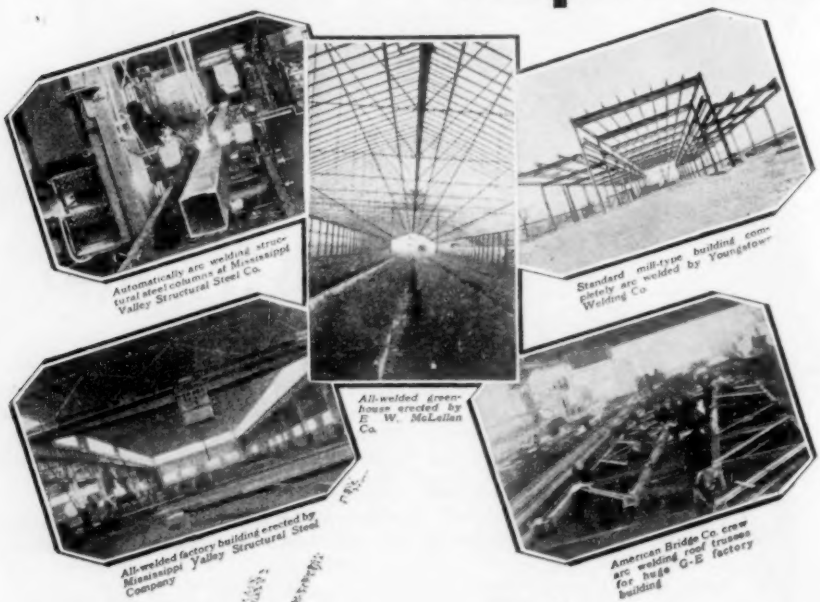
GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN PRINCIPAL CITIES

THE ARC WELDING AGE

It's coming FAST

Prepare Now!



Automatically arc welding structural steel columns at Mississippi Valley Structural Steel Co.

All-welded greenhouse erected by E. W. McLellan Co.

Standard mill-type building completely arc welded by Youngstown Welding Co.

All-welded factory building erected by Mississippi Valley Structural Steel Company

American Bridge Co. crew arc welding roof trusses for huge G-E factory building

THE MORE YOU ARC WELD THE MORE YOU SAVE

The experimental stage is passed. Arc Welding is here to stay. To sit back and wait is to lose your position in the field.

Prepare now for the Age of Arc Welding in building construction. Begin studying designs, tests, welding equipment, and costs.

General Electric has unusually complete files of arc welding application and cost data. It manufactures the only complete line of arc welding equipment. And it offers you the most complete service available anywhere. Prepare now by using this service.

530-40 D

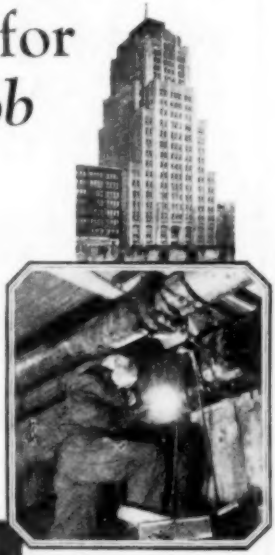
GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN PRINCIPAL CITIES

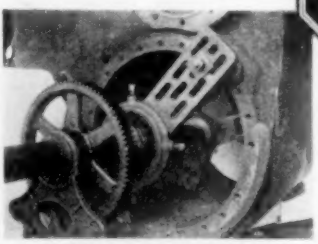
There's a Grade (analysis) of WILSON WIRE for *every arc-welding job*

SUCCESSFUL arc-welding demands the RIGHT wire for the *particular* metal which is to be welded. For instance, steel requires one analysis of wire; machineable welds on cast-iron another; and bronze, still another. And again, the purpose of the weld further determines the analysis required. Boiler work, where tensile strength is the vital factor, requires one analysis of wire; rail heads, where hardness is of first importance, require another analysis.

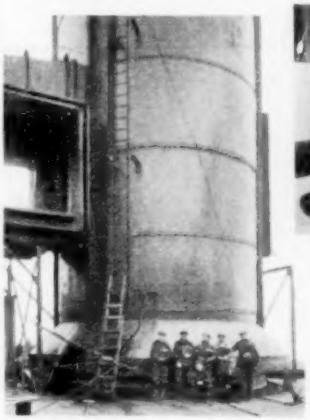
Wilson has developed a correct Grade (analysis) of wire for practically every welding purpose—each designated by a color, hence *"Color-tipt."* And every Grade of Wilson Wire is *uniform throughout.*



Above: Showing the Ohio Bell Telephone Building, Cleveland, and welder at work on one of the 16-inch Steam Risers that feed fifteen stories of the building. After exhaustive laboratory tests, Wilson Wire was chosen for every weld on this job. Wilson Grade No. 6 (patented U.S.A., June 13,1916; March 9, 1920; Canada, March 19, 1918) and Wilson Grade No. 9 (patented U.S.A., June 13, 1916; March 9, 1920) were used.



Above: Cracked locomotive cylinder Welded with Wilson Grade No. 12 (patented U. S. A., April 6, 1920; August 30, 1921).



At left: One of several stacks at the Edison Plant, 14th Street and East River, New York, on which Wilson Grade No. 17 (patented U. S. A., June 13, 1916; March 9, 1920) was used. All seams were welded on the inside to forestall corrosion from acid deposits. Each stack is 256 feet high and 22½ feet in diameter, and contains 8000 feet (1½ miles) of arc-welding.

Learn for yourself the superiority of Wilson Wire. Tell us the kind of welding you want to do, and we will send you a sample of the correct Grade.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE

Our Advertisers Are Supporting the Society.

The "SWEDOX LINE" of

WELDING RODS — WIRES — SUPPLIES
CARBON PLATES — RODS — PASTE
WELDING ELECTRODES and
GRAPHITE DISCS

IN ADDITION TO A COMPLETE STOCK OF WELDING SUPPLIES WE ALSO CARRY A COMPLETE STOCK OF HOT ROLLED AND COLD FINISHED STEELS OF EVERY DESCRIPTION.

Central Steel & Wire Company

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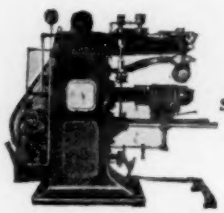
East Monument Ave.
Extended
Dayton, Ohio
East 150

5001 Bellevue Ave.
Detroit, Mich.
Whittier 6780

SPOT


SEAM

ARC

GIBB WELDING SERVICE EMBRACES

First—A complete line of Electrical Welding Equipment, making possible the best type machine for the job, taking all facts into account.

Second—Welding Engineers who quickly recognize the nature of a job, and who from experience and an intimate knowledge of our complete line are in a position to determine the best solution.

Third—An up-to-date factory capable of following out the ideas of the engineer and his client.

Fourth—Installation Engineers of experience with welding machines and their application to production.

Tell us what you want to weld—let us give you the benefit of our experience. Experience is the safe director.

GIBB WELDING MACHINES CO. - Bay City, Michigan

MANUFACTURERS OF ARC, SPOT, SEAM, BUTT AND AUTOMATIC ELECTRIC WELDING MACHINES
New York - Philadelphia - Cleveland - Cincinnati - Detroit - Chicago - St. Louis - Los Angeles
Toronto - Montreal

Roebling

Welding Wire

Strong welds are made only when the best electrodes are used. Roebling Welding Wire is manufactured to meet the most rigid specifications. It is uniform throughout each shipment and all shipments. Look for the JAR trade mark on each electrode.

John A. Roebling's
Sons Company
Trenton, N. J.
Makers of Wire
Rope and Wire

THERMIT WELDING

Proven, inexpensive, practical, and simple in its application to all classes of work involving the repair of medium and heavy size sections of iron and steel.

THERMIT
TRADE MARK REG. U.S. PAT. OFF.
GOLDSCHMIDT PATENTS

Railway
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Marine
Mining
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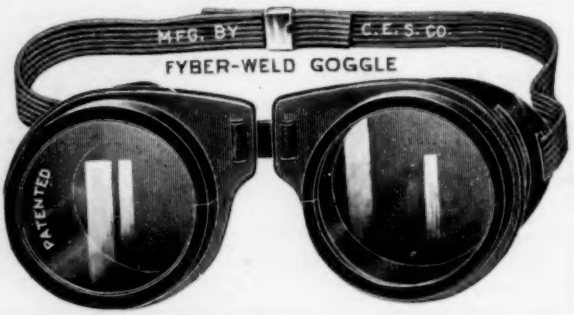
Metal & Thermit Corporation
120 Broadway, New York, N. Y.
So. San Francisco, Chicago, Pittsburgh, Boston, Toronto

MILBURN

Welding and Cutting Apparatus
Portable Carbide Lights
Oil Burners and Preheaters
Paint Spray Equipment

THE ALEXANDER MILBURN COMPANY
Established 1907
1416-1428 W. Baltimore St. Baltimore, Md.

Vision Protecton With ESSENTIALITE
glare proof welding glass
Made from a special glass that FILTERS the GLARE, producing a softer and more comfortable vision.
ESSENTIALITE LENSES ARE SCIENTIFICALLY CORRECT, for Electric Welding there are none better—they positively aid in conserving the eyesight of those who are subjected to welding glare.
Manufactured by
CHICAGO EYE SHIELD COMPANY
2300 Warren Ave. Chicago, Ill.
We make a full line for the face and head protection of the Welder.
Hand Shields, Helmets
Sand Blast Helmets
Goggles and Glass



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Now

get your *better* welding wire this *better way*

Page Welding Wire and Electrodes are now available in handy packages especially designed for the garage and small job welding shop.

All you have to do to get this better wire is tell your distributor the grade you need. You will get exactly what you want—quickly and conveniently. What is more—the carton will eliminate any chance of the wires being mixed. You can easily prove for yourself the efficiency and economy of Page Welding Wire and Electrodes in this new package form. Write for the name and address of your distributor. He will recommend the grade best suited to your work.

PAGE STEEL AND WIRE COMPANY

Bridgeport, Connecticut

District Offices: Chicago, New York, Pittsburgh, San Francisco
An Associate Company of the American Chain Company, Inc., Bridgeport, Conn.
In Canada: Frost Steel and Wire Co., Hamilton, Ontario

PAGE-ARMCO

Flame-Tested **PROCESSED** Shop-Tested

Welding Wire and Electrodes

AIR REDUCTION SALES COMPANY

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Buffalo	Jersey City	Richmond
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Chicago	Milwaukee	Seattle
Cleveland	Minneapolis	Wheeling, W. Va.

And 110 Distributing Stations

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